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CYPRESS BARK SCALE.[1]

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ECONOMIC IMPORTANCE.

The Monterey cypress (*Cupressus macrocarpa* Hartw.) is one of the most popular shade and ornamental trees in California. It is planted separately or in hedgerows and often trimmed to formal shapes. Due to its thick, spreading habits it makes a good windbreak where it is planted in exposed areas. It is used especially along the coast and in the sandy citrus areas of San Bernardino County. It is also cultivated as an ornamental tree in many other parts of the world.

The cypress bark scale infests a large percentage of these trees in California, causing a great deal of injury, particularly to the thickly planted hedgerows (Pl. I, figs. 1, 2) and windbreaks. In the San Francisco Bay region it ranks first among the pests of the

[1] *Ehrhornia cupressi* (Ehrhorn). Order Hemiptera, suborder Homoptera, family Coccidae.

NOTE.—An investigation made of the injury to cypress trees in California was taken up by the writer, at the suggestion of Dr. A. D. Hopkins, Forest Entomologist, in November, 1916. An examination made of these trees in the vicinity of the Los Gatos laboratory disclosed the main cause of the injury to be the cypress bark scale, *Ehrhornia cupressi* (Ehrhorn). This bulletin contains a record of studies of its history, biology, importance, and control made during this investigation.

The writer wishes to acknowledge the assistance of Dr. A. D. Hopkins, Forest Entomologist; Mr. H. E. Burke, Specialist in Forest Entomology; Prof. R. W. Doane and Mr. G. F. Ferris, of the Stanford University Department of Entomology; and Mr. George P. Gray, of the University of California Insecticide Laboratory, all of whom offered helpful suggestions during this study. Mr. R. D. Hartman assisted in the control experiments.

Monterey cypress. The insect is extremely difficult to control—a fact which makes it a very disagreeable and harmful pest.

HISTORY.

The cypress bark scale was first described in 1911 as *Sphaerococcus cupressi* by Mr. E. M. Ehrhorn[1] who collected it at Niles and San Jose, Calif., as early as 1903, and at Belvedere, Calif., in 1908, in the bark crevices of Monterey cypress. The next mention of this insect was in the report of the Selby Smelter Commission in 1915, when Mr. J. W. Blankinship[2] and Prof. R. W. Doane[2] reported it as one of the factors causing the death and dilapidation of the Monterey cypress in the Selby smoke zone. In October, 1918, Mr. G. F. Ferris,[3] with the writer's approval, erected a new genus, Ehrhornia, for this species, for it certainly was not a Sphaerococcus. Although an important shade-tree pest, no discussion of this insect has appeared in print otherwise, except for a short note by the writer[4] on its damage and distribution.

This coccid has no synonyms, having been listed under the name *Sphaerococcus cupressi* until the new genus, Ehrhornia, was erected in 1918, with *cupressi* as the type.

NATIVE HOST PLANT.

This scale insect could not be found at Cypress Point or Point Lobos, Calif., the only localities where the Monterey cypress is native, which showed quite conclusively that this tree was not the native host.

On November 9, 1917, the cypress bark scale was found infesting some planted trees of Arizona cypress (*Cupressus arizonica*) at San Jose, Calif., although it has not at the present writing been found on the native cypress in Arizona.

On December 6, 1917, this insect was found by the writer infesting one incense cedar (*Libocedrus decurrens*), and later several more trees, on the Stanford University campus. Later, the native incense cedars at Placerville, Calif., were examined. A number of them were found infested. They were several miles from any planted cypresses, which, moreover, were not infested.

Later, the cypress bark scale was found upon incense cedar at Ashland, Oreg., by Mr. Albert Wagner, of the United States Bureau of Entomology; at Crockers, Calif., by Mr. G. F. Ferris; and at

[1] EHRHORN, E. M. NEW COCCIDÆ WITH NOTES ON OTHER SPECIES. *In* Can. Ent., v. 43, no. 8, p. 275–280. (Figs. 3, 3a, b, c.) 1911.

[2] HOLMES, J. A., FRANKLIN, E. C., GOULD, R. A. REPORT OF THE SELBY SMELTER COMMISSION. U. S. Dept. Int., Bur. of Mines, Bul. 98, p. 381–597; 428–450. 1915.

[3] FERRIS, G. F. NOTES ON COCCIDÆ II. *In* Can. Ent. v. 50, no. 10, p. 323–332. 1916.

[4] MONTHLY LETTER OF THE BUREAU OF ENTOMOLOGY, U. S. Dept. Agr., no. 46, p. 5. February, 1918.

Stirling City and Giant Forest, Calif., by the writer. These localities are all from 75 to 150 miles apart and from 5 to 50 miles distant from any planted cypress. This seems to indicate that the incense cedar is the native host for this scale insect.

Mr. G. F. Ferris reports finding this scale insect upon herbarium specimens of Guadalupe cypress (*C. guadalupensis*) in the Stanford University herbarium, collected on Guadalupe Island, Mexico. It is impossible at present to state whether this is one of the native hosts of the scale, or whether the scale has been carried there from the mainland.

DISTRIBUTION AND SPREAD.

Incense cedar, the original host plant of the cypress bark scale, occurs in California, Oregon, western Nevada, and Lower California. The majority of these trees are found in the Sierra Nevada and northern coast range mountains of California, and in the Siskiyou, southern coast range, and Cascade Mountains of Oregon.

The cypress bark scale has been found at four widely separated points in the Sierra Nevadas (Stirling City, Placerville, Crockers, and Giant Forest, Calif.) and at one point in the Siskiyou Mountains (Ashland, Oreg.), which indicates that the scale undoubtedly occurs throughout the major portion of the range of the original host.

From this host the scale insect has spread to planted incense cedars and cypresses in the more thickly populated regions of the State. Two probable methods of distribution are suggested.

The cypress bark scale has been found to thrive on very young trees. Incense cedar seedlings occasionally are brought down from the Sierra Nevadas by tourists to plant in their own yards, and it is quite possible that the scale was carried to the valley on some of these trees. Rustic incense cedar is also transported from the Sierra Nevadas to be used quite extensively for pergolas and porch pillars. Ordinarily this would be done during the summer, which is the reproductive period for the scale insect. As the females can live for some time on green logs, it would be very easy for the young larvæ, hatched en route or after the logs have reached their destination, to attach themselves to near-by cypress trees, and thus start a heavy infestation in a new location.

From these original points of infestation the pest has spread through large areas. This has been accomplished for short distances by the usual agencies of wind, birds, insects, etc., and for longer distances by the shipment of infested nursery stock. The insect has been found by the writer infesting cypress seedlings in nurseries. Close planting of shade trees, hedges, and windbreaks undoubtedly aids in its rapid spread by natural means.

The scale insect, besides being distributed on the incense cedar, has now spread until it occurs on a large percentage of the cypress trees and hedges in almost every locality about San Francisco Bay, particularly on the San Francisco Peninsula, in the Santa Clara and Livermore Valleys, and north of the bay in Solano, Marin, and Sonoma Counties. It has been found in one locality, Riverside, in southern California, where a great many trees are planted for windbreaks. It is also to be found on Guadalupe Island, Mexico, as it was recently taken from herbarium specimens of Guadalupe cypress collected on this island.

The accompanying map (fig. 1) indicates the localities in which the cypress bark scale has been found to date, as well as the range of incense cedar and Monterey cypress. There are many localities within the range of cypress and incense cedar, which the writer has not yet visited, in which the scale insect will probably be found, when investigated. In all probability it eventually will infest all planted cypresses unless radical measures of control are adopted.

Since it has been found that the cypress bark scale can live on Arizona cypress, it is possible that it may spread to that host in Arizona and Mexico, or it may even be able to adapt itself to closely related hosts and spread throughout the country.

INJURY.

Injury to the tree is caused by the myriads of insects which are to be found in every crack and crevice of the trunk, branches, and twigs, each sucking out the plant juice through its long thread-like mouth parts. Under each scale may be found a small brown ring in the cambium, showing the tissue killed by each individual.

There is no secretion of honeydew, except for a small amount by the young larvæ, and only a slight formation of black sooty fungus about these insects, but a secretion of white cottony wax protruding from the bark crevices and covering the twigs gives abundant evidence of their presence (Pl. II).

First a limb or two on an infested cypress turns yellow, then red or brown, giving the tree (Pl. III) a scraggy appearance. This appearance often starts near the top of the tree and works down toward the center, or perhaps spreads from one limb to the rest until the whole tree is dead. Quite often the trees are dug up or felled before this final stage is reached; others are left to mar the landscape until they rot and fall.

In hedges, yellow and red spots appear, which increase finally to large proportions, leaving wide gaps of dead material which eventually destroy the beauty of whole hedges. One hedge in Livermore, nearly a half mile long, was infested and dead or dying

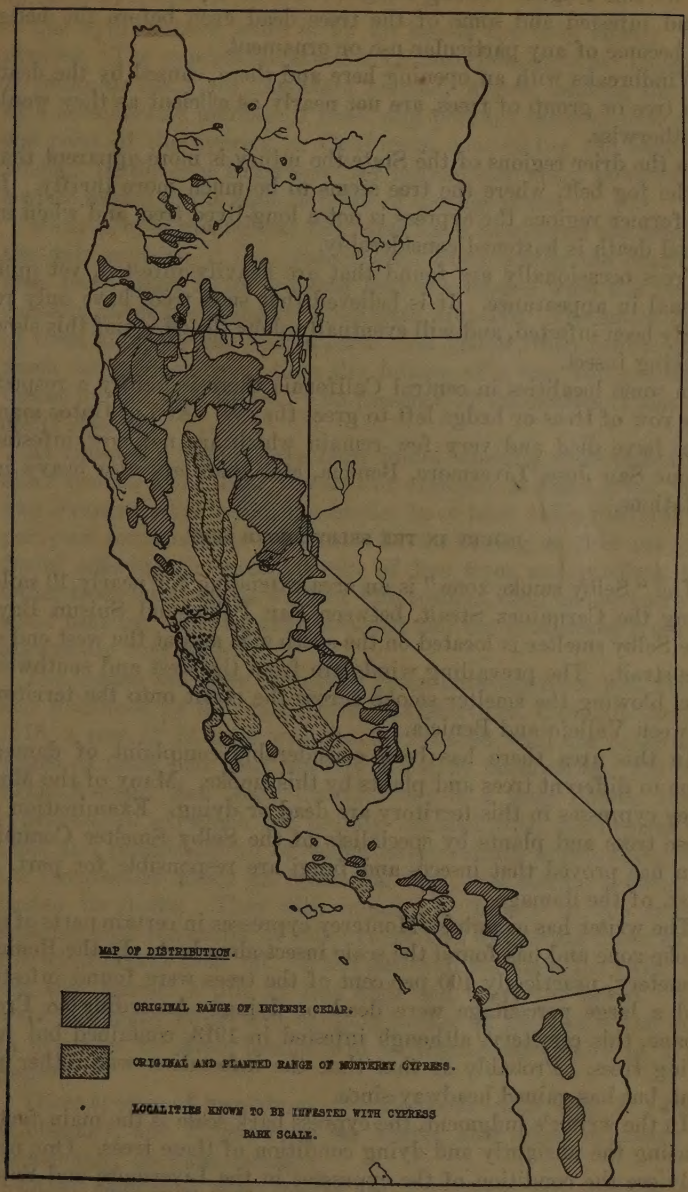

MAP OF DISTRIBUTION.
ORIGINAL RANGE OF INCENSE CEDAR.
ORIGINAL AND PLANTED RANGE OF MONTEREY CYPRESS.
LOCALITIES KNOWN TO BE INFESTED WITH CYPRESS BARK SCALE.

FIG. 1.—Map of distribution of the cypress bark scale.

for its full length. Young hedges but 3 or 4 years old have been found infested and some of the trees dead even before the hedge has become of any particular use or ornament.

Windbreaks with an opening here and there, caused by the death of a tree or group of trees, are not nearly as efficient as they would be otherwise.

In the drier regions of the State the injury is more apparent than in the fog belt, where the tree seems to be much more thrifty. In the former regions the cypress is not a long-lived tree, and when infested death is hastened considerably.

Trees occasionally are found that are heavily infested, yet quite normal in appearance. It is believed that such trees have only recently been infested, and will eventually show the effects of this slow-working insect.

In some localities in central California there is hardly a respectable row of trees or hedge left to greet the eye. At Los Gatos many trees have died and very few remain which are not now infested. About San Jose, Livermore, Benicia, etc., there are also heavy infestations.

INJURY IN THE SELBY SMOKE ZONE.

The "Selby smoke zone" is an area extending for nearly 10 miles along the Carquinez Strait, between San Pablo and Suisun Bays. The Selby smelter is located on the south side and at the west end of this strait. The prevailing winds are from the west and southwest, thus blowing the smelter smoke across the strait onto the territory between Vallejo and Benicia.

In this area there has been considerable complaint of damage done to different trees and plants by this smoke. Many of the Monterey cypresses in this territory are dead or dying. Examination of these trees and plants by specialists of the Selby Smelter Commission has proved that insects and fungi are responsible for part, at least, of the damage.

The writer has examined Monterey cypresses in certain parts of the smoke zone and has found the scale insect abundant. In the Benicia Cemetery, practically 100 per cent of the trees were found infested and a large percentage were dead or dying. According to Prof. Doane, this cemetery, although infested in 1913, contained but few dying trees. Probably at that time the infestation was rather recent, but has gained headway since.

In the writer's judgment, the cypress bark scale is the main factor causing the unsightly and dying condition of these trees. One need only see the condition of the cypresses in the Livermore and Santa Clara Valleys to reach this conclusion.

ASSOCIATED INSECTS.

The cypress bark scale is by no means the only enemy of the cypress. The cypress barkbeetles (*Phloeosinus cupressi* Hopk. and *P. cristatus* Lec.) are important primary insects, causing the death of a considerable number of trees, and perhaps ranking first among the pests of the cypress in California, considering the State as a whole. In the San Francisco Bay region they must, however, take a place second to the scale in point of damage done.

Many people throughout the State have considered the beetles as the only enemies of the cypress, and, when noting the death of a tree, have taken it for granted that the beetles were the primary cause, without bothering to investigate properly. The entire foliage of trees killed by the beetles turns first yellow, then brown, and is much more conspicuous than the foliage of a tree being killed by inches by the scale insect. The presence of the beetles is also more easily detected.

At times the beetles have been found working independently of other insects, and killing trees. For example, at San Carlos, on the San Francisco Peninsula, the beetles have been killing several trees per year for a number of years. In the spring of 1918 they were found entering the green trunks of live trees and girdling them. Other trees showing the work of Phloeosinus, dead one or two years, stood near by. The recently attacked and the unattacked trees were apparently very healthy.

The beetles are often secondary pests, entering trees well infested and weakened by the scale insect. At Martinez, Calif., in January, 1918, a row of 12 trees was heavily infested with the scale insect. Three of these had been recently killed by barkbeetles. On Alum Rock Avenue, San Jose, Calif., there is a long double row of cypresses, all of which are heavily infested with the cypress bark scale and practically all of which have a sickly appearance. Here the barkbeetles attack an occasional tree, or a section thereof, and hasten its death. They also impair the beauty of the trees by entering into the center of small twigs and weakening them, so that the wind breaks them off. When gathered together, the twigs from one tree formed a pile 2½ feet high and nearly as broad. There were also many twigs still hanging broken in the tree. The injury to cypresses by these beetles will be treated separately in a later paper.

Three species of mealybugs, *Pseudococcus ryani* Coq., *P. sequoiae* (Coleman), and *P. cupressicolus* Ferris, also infest cypresses and occasionally do some damage.

Other associated scale insects are *Xylococcus macrocarpae* Coleman, *Lecanium corni* Bouché, *Diaspis carueli* Targ., *Aspidiotus*

hederae (Vallot), and *Aspidiotus ehrhorni* Coleman. None of these have been noted doing any considerable damage.

Still other associated insects of various orders are: *Phymatodes nitidus* Lec., *Atimia confusa* Say, *Trachykele blondeli* Mars., the cypress moth (*Argyresthia cupressella* Wals.), the cypress coneborer (*Cydia cupressana* Kear.), a horn-tail wasp (*Sirex californicus* Ashm.), the arborvitæ plant-louse (*Lachniella tujafilina* Del Guer.), and an undetermined tussock moth.

FOOD PLANTS.

The known food plants of the cypress bark scale are: Monterey cypress (*Cupressus macrocarpa* Hartw.), Arizona cypress (*C. arizonica* Greene), Guadalupe cypress (*C. guadalupensis* Wats.), and incense cedar (*Libocedrus decurrens* Torr.). On one other tree, a deodar cedar (*Cedrus deodara* Loud.), at Santa Rosa, Calif., a dead male was found in its cocoon.

It seems strange that the scale insect should not occur on all species of cypress if it will infest two trees as different as Monterey cypress and incense cedar, yet Italian and Oriental cypresses, two varieties of *Cupressus sempervirens*, are immune to the attack of this insect. They have been found in many instances in close proximity to infested Monterey cypresses and entirely free from the scale insect. In one case, in the Benicia Cemetery, 27 cypresses formed a square about a plot. Two-thirds of these were Monterey cypresses, with every third tree an Italian cypress, touching a Monterey cypress on each side. Every Monterey cypress was infested and dead or dying, while not a scale could be found on the Italian cypresses.

Specimens of Himalayan cypress (*C. torulosa* Don.), Macnab cypress (*C. macnabiana* Murray), funeral cypress (*C. funebris* Endl.), Sargent cypress (*C. sargentii* Jepson), and Port Orford cedar (*Chamaecyparis lawsoniana* (Murr.) Parl.) have been examined, although not in large numbers, within the infested areas, and no cypress bark scales could be found upon them.

DESCRIPTION.[1]

THE EGG.

Egg (Pl. IV, *A*), immediately after being deposited, regularly oval, smooth, and shiny, of a transparent pale yellow color, with eyes of embryo visible through membrane as two dark spots near one end. Average length of seven eggs 0.34; mm.; width 0.14.

LARVA.

FIRST INSTAR.

Young larvæ (Pl. IV, *B*) of both sexes alike. Pale yellow in color, with long, flat, oval bodies 0.43 mm. in length, 0.20 mm. in width. Antennæ (Pl. V,

[1] The following detailed description of all stages from the egg to adult, both male and female, were made from living and freshly mounted material collected during the study of the cypress bark scale.

FIG. 1.—A TALL MONTEREY CYPRESS HEDGE, SHOWING MANY DEAD SPOTS CAUSED BY THE CYPRESS BARK SCALE.

FIG. 2.—A MONTEREY CYPRESS HEDGE KILLED BY THE CYPRESS BARK SCALE.

FIG. 1.—CHARACTERISTIC INFESTATION ON MONTEREY CYPRESS TWIG, SHOWING THE COTTONY EXCRETIONS OF THE CYPRESS BARK SCALE. × 0.4.

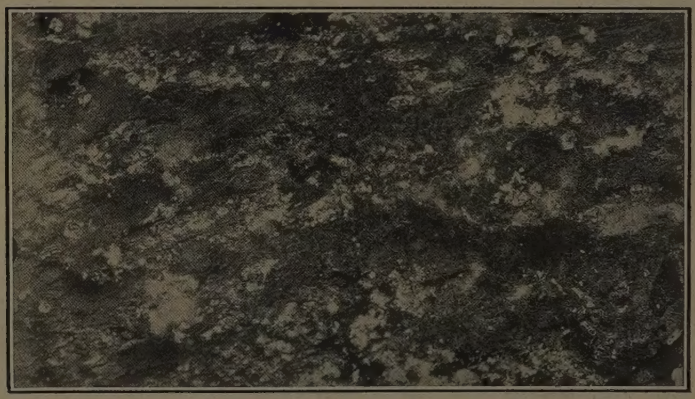


FIG. 2.—CHARACTERISTIC INFESTATION ON THE BARK, THE COTTONY EXCRETIONS OF THE CYPRESS BARK SCALE PROTRUDING FROM THE CREVICES. × 2.

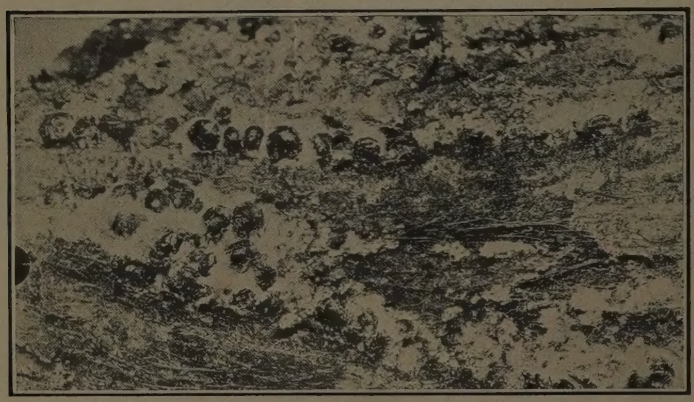
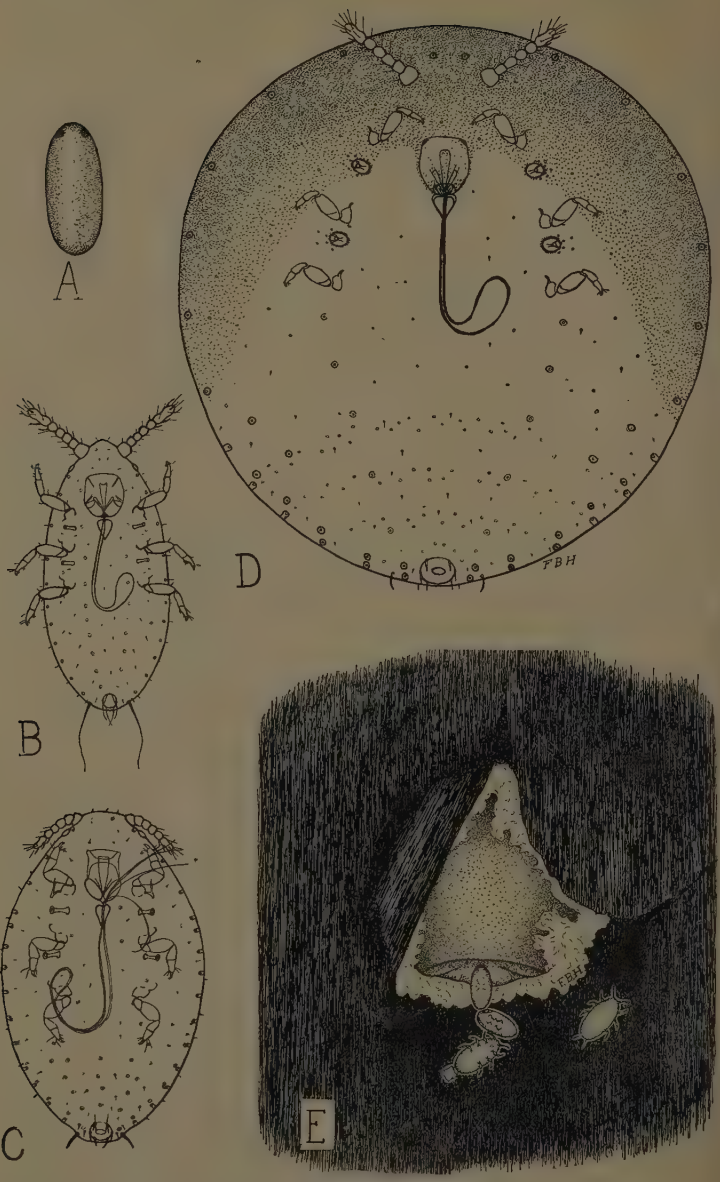


FIG. 3.—THE DRY OUTER PORTIONS OF THE BARK REMOVED, REVEALING THE FEMALES OF THE CYPRESS BARK SCALE UNDERNEATH. × 4.

FIG. 1.—A MONTEREY CYPRESS WHICH IS NEARLY DEAD FROM THE WORK OF THE CYPRESS BARK SCALE.

FIG. 2.—A ROW OF MONTEREY CYPRESSES, ALL OF WHICH ARE PRACTICALLY DEAD FROM A CYPRESS BARK SCALE INFESTATION.



THE CYPRESS BARK SCALE.

A, Egg (× 55); *B*, larva, first instar (× 85); *C*, female larva, second instar (× 55); *D*, adult female (× 55); *E*, portion of bark removed, showing adult female depositing eggs, the eggs hatching, and the larva crawling away.

A, 2) six-segmented, first segment broadest, sixth longest. Normal antennal formula as follows: 6, 1, (2, 4, 3, 5). Joints 2, 3, 4, 5 subequal and variable, thus causing various formulæ. Antennæ rather hairy. Fifth segment bearing one broad spine, while four occur on sixth segment. Eyes marginal, set a short distance behind antennæ. Legs rather short and stout. Tarsus slightly longer than tibia, the two combined slightly longer than femur and trochanter combined. Legs rather hairy, tarsi bearing four knobbed digitules. Usual coccid sucking mouthparts present. About 26 trilocular pores set rather regularly about margin and two longitudinal rows of the same type on dorsum of insect. Caudal setæ (Pl. V, *B*, 1) prominent, rather stout, and about 140 μ long; borne on small inconspicuous anal lobes. Anal ring bearing six setæ, noticeably longer than in later stages. A number of short spines scattered over body.

SECOND INSTAR.

Immediately after the first molt some differences between the sexes can be detected under the microscope. Toward the end of the second stage an external difference can be observed in the shape, the female being broader than the male.

Female larva (Pl. IV, *C*) about 0.84 mm. long and 0.51 mm. wide, oval in outline, yellowish brown in color. Legs and eyes similar to those of first-stage larva. Antennæ very similaf except that sixth segment bears only two broad spines. Caudal setæ (Pl. V, *B*, 3) much shorter, being only 37 μ long. Anal ring still bearing six hairs, also shorter than in preceding stage. A larger number of tubular wax ducts, varying from 40 to 75, to be found on dorsum, particularly abdomen, and on lateral margin. Also a number of trilocular pores and small spines scattered over body.

Male larva (Pl. VI, *A*) about the same length but narrower than female; 0.85 mm. long by 0.43 mm. wide. Color yellowish. Caudal setæ twice as long as those of female, half as long as those of first-instar larva, 75μ. Six anal hairs, in length equaling diameter of anal ring; longer than those of second-stage female, but shorter than those of first-stage larva. Pores of male larva very inconspicuous (Pl. V, *D*, 2), smaller than those of female. Small quinquelocular type pores scattered over both dorsum and venter of body. Small tubular ducts found mostly on margin. Small spines also present.

ADULT FEMALE, THIRD INSTAR.

Body (Pl. IV, *D*) nearly circular and quite convex, the width exceeding the depth and the length exceeding the width. Average length 1.45 mm., average width 1.35 mm. General color reddish brown. Anterior half of body quite heavily chitinized, particularly on margin. Derm smooth.

Antennæ (Pl. V, *A*, 3) no longer marginal, but occurring on ventral side of body, six-segmented, slightly longer, averaging 144 μ, but similar to those of second-instar larva, bearing only two of the four spines found on sixth segment of first-instar larva. As in larva antennal formula varying considerably, of practically no value. Average formula as follows: 6, 1, 3, (5, 2, 4). Eyes lacking.

Legs (Pl. V, *C*, 1) short and stout. Tibia and tarsus (Pl. V, *C*, 2) subequal, being together slightly shorter than trochanter and femur combined. Leg bearing a few hairs and tarsus bearing four knobbed digitules. Usual coccid mouthparts present. Large tubular ducts (Pl. V, *D*, 1) occurring on margin and dorsum of body. Small trilocular pores and fine spines scattered over body, particularly on abdomen. Anal ring (Pl. V, *B*, 4) occurring on ventral side of body, small, simple, and with six small setæ or hairs. A pair of small caudal setæ one on each side of anus. Anal lobes absent.

MALE PREPUPA.

With the second molt, the male larva assumes the form of a partly developed pupa, called the prepupa (Pl. VI, *B*). Form elongate oval; length 0.93 mm., width 0.50 mm. Color pale glassy brown, eyes black. Antennæ short, reaching to base of anterior legs and now indistinctly 10 segmented. Wing pads very short, curving under body to middle pair of legs. Anterior legs reaching forward, covering "face," the two posterior pairs lying against abdomen. Mouth parts wanting. Segmentation of thorax indistinct. Prepupa incapable of movement, except in abdominal segments and anterior legs, which may be feebly moved.

MALE PUPA.

With the third molt, the male becomes a true pupa (Pl. VI, *C*), greatly resembling the adult male, except for the lack of anal wax filaments, and the possession of wing pads instead of wings. General color light brown, head and large, conspicuous wing pads paler, legs and antennæ glassy white, eyes black. Antennæ distinctly 10-segmented and longer, reaching to base of middle pair of legs. Wing pads appressed to sides of body and extending posteriorly to second abdominal segment. Legs capable of some movement, anterior pair extending beyond the head; middle femora placed transverse to and extending beyond lateral margin of body, rear pair inclining posteriorly. The larval eyes have disappeared, and have been replaced by one dorsal and one ventral pair. Mouth parts replaced by an approximate pair of eyes. Length 0.95 mm.; width 0.45 mm.

ADULT MALE.

(Pl. VI, *D, E.*)

Measurements of average adult male: Length of body (exclusive of appendages) 0.75 mm.; antennæ 0.55 mm.; wax filaments 0.93 mm.; wing expanse 2.15 mm. General color light brown with paler brown appendages.

Antennæ (Pl. V. *A*, 1) 10-segmented, rather hairy, first joint short and broad, second rather long and broad, others more slender. Antennal formula: 3, 4, 5, 6, 7, 8, 9 (10, 2), 1. Legs rather long, slender, and somewhat hairy. Wings transparent white, slightly iridescent and pubescent. A veinlike thickening, beginning at base of wing, branching near base, one branch paralleling costal margin, the other extending toward anal distal margin. Club-shaped halteres each bearing a hook, which catches in a pocket on anal margin of wing. Abdomen terminating in a short blunt style. Two long white wax filaments arising one on either side of base of style, and extending posteriorly. Each filament arising from a number of pores which surround base of two long slender setæ. Setæ enveloped by wax filaments.

SUMMARY.

As will be noted from the foregoing descriptions, there are three instars (excluding the egg) in the female. These all have legs, which are not used after the larva is attached. All stages are found in crevices or under some covering on the bark and are nearly or completely concealed by the enveloping cottony wax. Newly hatched first-instar larvæ may be found crawling actively over the bark before attachment.

There are five stages in the male. The first two stages are found in similar positions, but the second stage after becoming full grown re-

moves to a dry, secluded spot, where it spins a cocoon in which the remaining transformations take place.

Size and shape are of some use in distinguishing the different stages. The female in its second stage is considerably broader than the male in the second stage, while both are larger than in the first stage. The adult female is more circular than in the preceding stage.

The antennæ of the adult female are slightly longer than the antennæ of second-stage larvæ, while the latter are slightly longer than those of the first-stage larvæ. All are very similar, however, the only distinguishing character being that the first-stage larva possesses two more broad spines on the sixth segment.

The three pairs of legs on each individual are alike, nor is there any difference between the larvæ and the adult female, except a very slight one in the relative lengths of the femur, tibia, and tarsus. Mr. Ehrhorn's figures indicate a difference in the arrangement of the hairs and digitules, which the writer has been unable to detect. There is a very small, scarcely discernible, tooth or "denticle" on the face of the claw in all these stages.

The caudal setæ give good characters for the separation of the different stages. On the first-stage larva they are about 140 microns long; on the second-stage male they are about half as long, 75 microns; those of the second-stage female half as long as the latter, 37 microns; and those of the adult female very much shorter still. The length of the setæ on the anal ring also decreases in the same ratio.

Simple marginal eyes are present in all the larval stages, but not in the adult female. Mouth parts are present in all stages, except in the male prepupa, pupa, and adult.

Four spiracles are present in all the larvæ and the adult female, one behind each of the four forward legs. In the larvæ they appear as simple tubes, and more as large chitinized circles in the adult female.

There are several types of pores found on the derm of the scale insect, which aid in distinguishing the different stages. The small sessile pores are of two types, viz., "trilocular" (Pl. V, *D*, 4) and "quinquelocular" (Pl. V, *D*, 5). The former are more or less triangular and contain three cells or loculi. The quinquelocular pores are nearly circular, but tend to be five-sided, containing ordinarily six loculi, one in the center with five clustered about it. Aside from these there are circular pores communicating with internal ducts. These are short and tubular, bearing at the inner end a cup-shaped depression. All types are presumably capable of secreting wax.

The first-stage larva bears only small pores of the trilocular type. These are arranged in a marginal row on each side of the body and in two longitudinal rows on the dorsum.

On the second-stage female larva are to be found the small trilocular pores scattered over the body, and from 40 to 75 of the large tubular ducts on the margin and dorsum (particularly on the abdomen). The pores of the second-stage male larva are of two types: The small quinquelocular type which are found all over the body, and tubular ducts similar to those of the second-stage female larva, but much smaller and less conspicuous, found mostly on the margin.

The pores and ducts of the adult female are of the trilocular and tubular types, the first scattered over the body and the latter occurring on the margin and dorsum of the body, much the same as in the second-stage female larva.

Small spines (Pl. V, *D*, 3) are present on all these stages. Viewed from above, these spines are likely to have the appearance of circular pores, but can be soon distinguished by altering the focus of the microscope.

LIFE HISTORY AND HABITS.

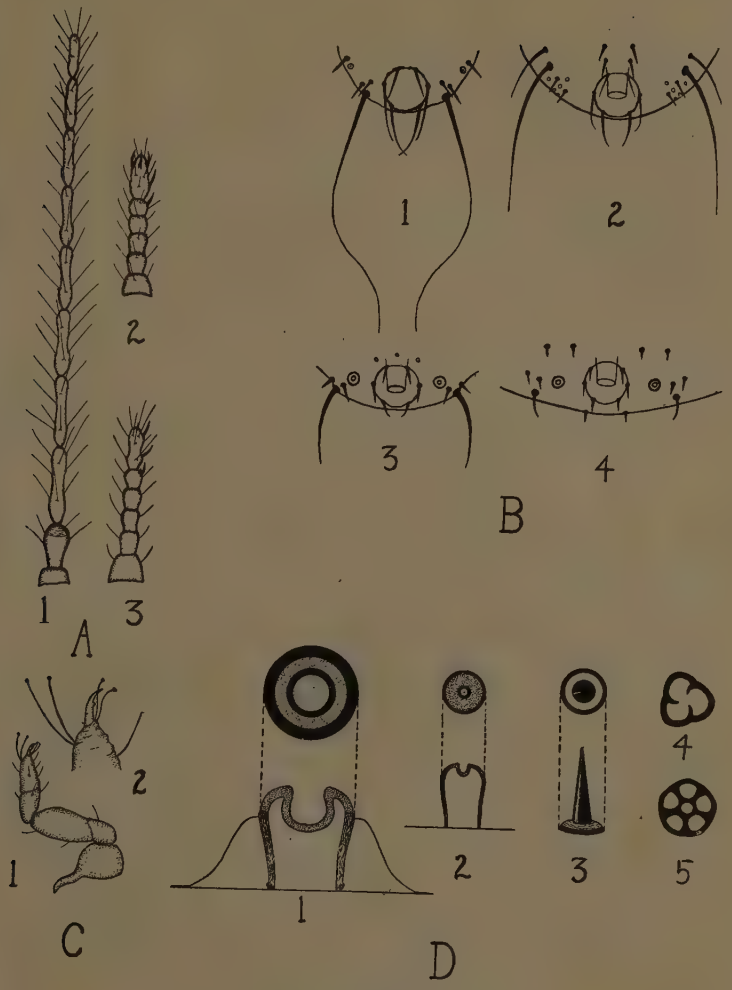
In the early winter adult females are found containing a few eggs. The eggs increase in number and by early spring from 30 to over 100 may be found within each female. During this time the females have increased considerably in size and have become quite heavily chitinized on the anterior half of the body.

OVIPOSITION.

The embryos in the eggs develop within the body of the female until they are about ready to hatch, when they are expelled (Pl. IV, *E*). The female is well surrounded by a cottony secretion, but when oviposition is begun the tip of the abdomen is drawn in, leaving a space in which the eggs may remain until hatched. After hatching, the larvæ are usually able to find an exit between the cotton and the surrounding bark.

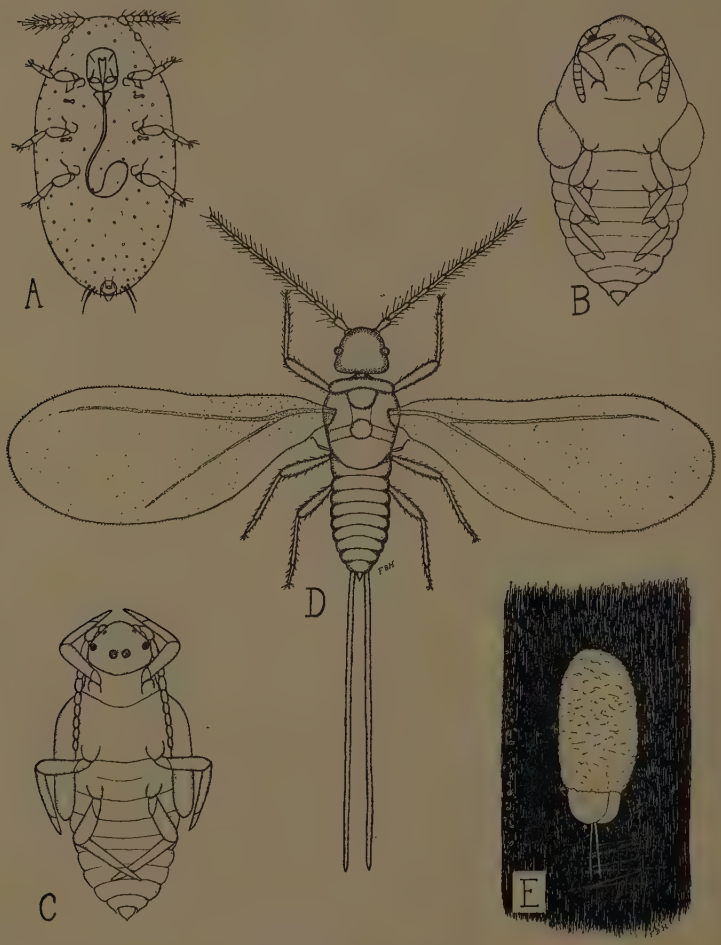
Each female is capable of laying 50 to 100 or more eggs. The greatest number of eggs that has been found within a female at any one time is 105. The eggs are laid slowly, covering a long period of time. They are laid during the warmer part of the day at intervals of 7 to 70 minutes. After laying a series of 5 to 10 eggs, the female ceases oviposition for a day or so and then resumes it.

Most of the embryos in the eggs are deposited tail first, about one-sixth being deposited head first. The head end of the embryo is evidenced by the two black eyes which are visible through the egg membrane. By a series of contractions of the abdomen, the egg is forced out until entirely free from the body of the adult. These eggs are oblong oval when first deposited, but flatten out somewhat before the rupturing of the membrane occurs.



THE CYPRESS BARK SCALE.

A, Antennæ: 1, adult male; 2, first-stage larva; 3, adult female (same as second-stage larva); *B*, Tip of abdomen, showing anal rings and caudal setæ: 1, first-stage larva; 2, second-stage male; 3, second-stage female; 4, adult female; *C*: 1, leg of adult female; 2, tip of tarsus and claw; *D*, Ducts and pores: 1, large pore and tubular duct of adult female; 2, small pore and tubular duct of second-stage male; 3, spine; 4, trilocular pore; 5, quinquelocular pore.



THE CYPRESS BARK SCALE.

A, Male larva, second instar (× 50) (male and female first-instar larvæ are identical); *B*, male prepupa (× 50); *C*, male pupa (× 50); *D*, male adult (× 50); *E*, male adult ready to emerge from cocoon.

About 15 minutes after the eggs are deposited, the embryo starts a series of convulsions and after considerable struggling ruptures the membrane inclosing it. The ruptured membrane is pushed down over the abdomen and the larva, which is usually on its back, begins waving its legs about in the air. It usually takes this larva 20 to 30 minutes to free itself from the membrane, and after exercising its legs for 30 or 40 minutes it finally gets to its feet and crawls away (Pl. IV, *E*). The larva quite often is stuck to the next expelled egg and may be held out in space for some time, but the struggles of one or the other finally allow the feet of the larva to touch foundation, where it soon makes use of them.

MIGRATION.

The larvæ become very active soon after exclusion and begin searching for a suitable spot upon which to locate. The majority of them immediately work down into the bark crevices or under the cottony secretions of the parent females, where they become attached. Some seem more fastidious than others and travel farther in search of newer feeding grounds. Recently hatched larvæ when placed upon favorable young trees do not travel far, and usually settle down after investigating two or three crevices in the bark.

Larvæ placed upon paper were able to travel considerable distances. (See fig. 2.) The average rate of travel for six larvæ was 54.25 cm. per hour, which they were able to maintain for several hours. The greatest distance traveled by one larva was 174 cm. in two hours. One larva, after traveling 124.46 cm. in four hours, apparently put its last efforts into trying to pierce the paper with its proboscis. Table I gives the time, distance, and rate per hour traveled by six cypress bark scale larvæ on black paper for the first few hours of their migration. Black paper was used in order to facilitate following the tiny pale larvæ in their wanderings. When white paper was used the larvæ were soon lost. There seemed to be a slight phototropism in the case of most larvæ, the majority of them finally wandering toward the light.

TABLE I.—*Record of travel of six first-instar larvæ of the cypress bark scale on rather smooth black paper.*

No.	Time.	Distance.	Rate per hour.
	Hours.	*Cm.*	*Cm.*
1	1.5	109.22	72.81
2	2.5	143.51	57.40
3	4.0	124.46	31.11
4	2.0	173.99	86.99
5	2.0	142.24	71.12
6	2.0	66.04	33.02
Average.	2.333	126.577	54.255

Larvæ isolated in vials, immediately after hatching, lived for two and three days. Living for this length of time and traveling at the above rate of speed during only the warmer parts of the day, larvæ could go considerable distances in search of proper food. In this way larvæ are able to migrate from one tree to another in closely planted hedges or windbreaks. During this migratory period, larvæ are also likely to be transported short distances by dropping from high

FIG. 2.—Tracings of five first-instar larvæ of the cypress bark scale during migration. Reduced 5½ times. All were started from the same center.

branches and being carried by the wind, and for longer distances by animate agencies, such as insects, birds, and animals.

ATTACHMENT.

As soon as a larva finds a suitable crevice or a protected area in the bark, it thrusts its proboscis into the bark tissues, where it remains permanently. Larvæ have not been known to remove themselves from this first location to another after once becoming attached. Larvæ which have become detached somewhat later in life are able to crawl about feebly, but finally die without being able to attach

themselves again. Although the legs are retained throughout the full lifetime, they are of no further use to the female larva except to aid in removing the cast skins when molting.

Larvæ will attach themselves on twigs as small as one-fourth inch in diameter and on trunks a foot or more in diameter, provided the bark is not too thick to be pierced with their proboscides. A few scale insects have been found infesting the smooth trunk of seedlings less than one-half inch in diameter, but rough bark is essential to a heavy infestation. The deeper the larvæ are able to go into the crevices the more satisfied they appear to be. They have been found so well secreted in crevices that it would seem there was no room left for their future growth, and much less any chance of mating, particularly after being enveloped with a white flocculent secretion.

LARVA.

FIRST INSTAR.

Immediately after attachment the larva begins enveloping itself with this white cotton until entirely hidden from view. A drop of honeydew, resembling pitch, is emitted by some larvæ, especially on vigorous trees, during the first few weeks after attachment.

Growth starts immediately after attachment and is practically constant throughout the whole instar. The larva at the end of the instar is very similar to those just hatched, except that the former are larger, somewhat broader in proportion to their length, and slightly darker in color.

At the end of the first instar, the larva molts, the skin being pushed down off the tip of the abdomen. From 40 to 44 days were required to complete the first instar in the few cases observed.

SECOND INSTAR.

There is very little development during the second stage. The female larva secretes more waxy cotton and changes in size and shape until it resembles the adult female. After a period of from one to two months the second molt occurs and the larva becomes an immature adult.

The male larva increases in size and becomes yellowish white in color. It takes on a firmer and trimmer appearance. After a slightly shorter time than that required by the female larva, the male larva detaches itself and crawls about in search of a favorable place in which to pupate. It may pick a spot under some cotton or in a curl of the outer bark. Cocoons have also been found in the cast skins of coccinellid larvæ and in the ruptured bodies of dead female scale insects.

Here the male larva proceeds to spin a cocoon, secreting cottony wax from the small ducts which occur on both the dorsum and venter of the body, turning over and over in the operation. The cotton secreted is finer than that secreted by the female larva, as would be expected because of the smaller ducts on the male.

It requires three or four days to complete the cocoon. After a day or two of inactivity, the larva molts to a prepupa, pushing the cast skin out through a slit which is in the rear end of the cocoon.

MALE PREPUPA AND PUPA.

The male from now on is without mouth parts, and during this dormant period is an inactive creature, capable only of feebly waving its front legs and wriggling its abdomen when disturbed.

The male remains in this stage from 10 to 15 days, and with this molt becomes a true pupa, greatly resembling the adult male. As in the previous stage, the pupa is inactive. Normally the same length of time is required for this stage as for the previous one. A few pupæ have been found hibernating in the colder Sierras.

ADULT.

MALE.

When the pupal skin is cast, the male's wings are extended to their full size and then folded, one over the other, upon its back. As soon as the wax filaments have grown to their full length, which requires from 30 minutes to several hours, the male backs out of the cocoon and becomes very active. It immediately begins searching for a mate. The length of life of the male is never more than one or two days and death occurs very soon after mating.

FEMALE.

The color of the female becomes darker after the second and last molt, and upon becoming heavily chitinized is a dark reddish brown. After mating the body increases considerably in size, becoming nearly globular. Inside the female's body may be found a large number of eggs in different stages of development. The body still is covered quite thoroughly with cotton and deeply hidden in the bark crevices. Upon becoming an adult a new supply of coarser threads of wax is excreted. After depositing the eggs, an act which covers a considerable period of time, the female shrivels and dies, nothing but the chitinized skin remaining. If the host plant is still alive, this vacancy is soon filled by a female of the next generation.

SEASONAL HISTORY.

(Fig. 3.)

There is but one generation per year, the limits of which are not very definite. The males appear in the fall, being most abundant in

October and November. These mate and die in a few days. At this time most of the females have cast their last skin and are about one-half grown.

The winter is passed as adult females, with no very definite period of hibernation in the lower altitudes. In the Sierra Nevadas there is a more definite period of hibernation and the generations are more even. The female larvæ become adults somewhat earlier in the fall. When the cold weather strikes them, development becomes very slow. In December females are found containing a few eggs. These develop during the winter and early spring.

Oviposition begins on the first warm days of spring and lasts throughout the summer, beginning about April 1 and terminating the latter part of September. In the fall the females, having com-

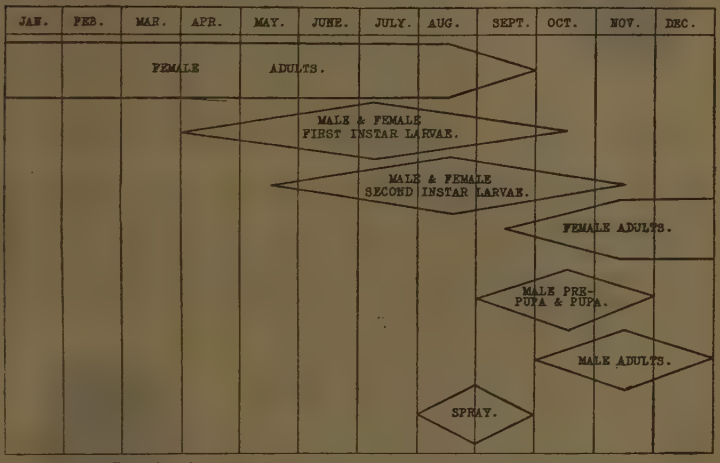


FIG. 3.—Seasonal history diagram of the cypress bark scale.

pleted oviposition, shrivel and die. By this time the young females of the next generation are quite well developed, thus assuring the presence of adult females during the whole year.

The larvæ issue from the eggs 30 or 40 minutes after deposition and soon attach themselves. Larvæ of the first instar may be found from April to the middle of October, second-instar larvæ from the middle of May to the middle of November, and adult females from about September 15 to the following September. Male prepupæ and pupæ may be found in September, October, and November, and adults in October, November, and December. A male pupa was found hibernating in the Sierra Nevadas. A few scattering first and second stage larvæ may be found during the winter in the milder climate near the coast.

PREDACIOUS AND PARASITIC ENEMIES.

There are several coccinellids which aid in the control of the cypress bark scale. None of them is aggressive enough, however, to affect its abundance very materially.

A very small ladybird, *Nipus biplagiatus* Casey (fig. 4), is the most abundant and widespread enemy of the scale. This is a sturdy little beetle, about 1.3 mm. in length, brownish black, with a lighter amber spot in the center of each elytron. It is generally present wherever the scale insect is to be found. On one side of a cypress limb in a space 3½ by 24 inches (84 square inches), there were found 46 specimens of this coccinellid and in certain parts of this area there were as many as four beetles to the square inch. There were undoubtedly still more out of sight under the bark scales. Very few of the larvæ of this beetle were seen but this may be accounted for by their extremely small size and their pale brown color.

FIG. 4.—*Nipus biplagiatus*, a coccinellid enemy of the cypress bark scale. × 25.

A small black nitidulid beetle, *Cybocephalus californicus* Horn (fig. 5), is very abundant and is sometimes confused with the above coccinellid. It is, however, slightly smaller, shiny black, with more delicate legs, and of a more compact globose form. This beetle has not been seen actually feeding upon the scale insect, yet it is believed to be an aggressive predacious enemy. It is always found about the scale insect, and often with its head in the bark crevices as if feeding upon the scale insect. The larva of this beetle is small and white and not easily found.

FIG. 5.—*Cybocephalus californicus*, a nitidulid beetle always found about the cypress bark scale. × 25.

The twice-stabbed ladybird, *Chilocorus bivulnerus* Muls., is an abundant and aggressive predator upon the cypress bark scale. This beetle is often found upon cypress, feeding upon this insect pest.

The common black-spotted red ladybird, *Hippodamia convergens* Guérin, has been found a few times feeding upon the scale. As this beetle breeds in great numbers in the Sierra Nevadas, it probably feeds upon the scale on incense cedar in its native haunt.

Larvæ of the common brown lacewing, *Sympherobius angustus* Banks, are often found feeding upon the cypress bark scale and aiding materially in retarding its increase and spread.

A few specimens of a small hymenopterous parasite have been reared from caged material of this scale insect. It can not, however,

be considered as of any importance, because of its great scarcity. In all the writer's observations but three scale insects have been found with punctures in them, from which parasites have escaped. Two of them were from Monterey cypress and one from incense cedar in the Sierra Nevadas. The scarcity of this scale insect in the Sierras would indicate that a parasite was quite active upon it. If such is the case, it has not as yet been noted.

CONTROL EXPERIMENTS.

A series of experiments was undertaken in order to find one or more materials capable of reducing the numbers of this very harmful pest. Only those sprays were experimented with which would be able to penetrate well into the crevices of the bark, where many of the scales were located. Oil sprays are the only ones which meet these requirements, consequently no others were tried. The oil sprays are capable of penetrating and creeping into all the tiny cracks and crevices of the bark when properly applied. The higher the gravity of oil used, the better is the penetration.

First, crude-oil emulsion was used, but, being a low-gravity oil, it was unsatisfactory. Next, distillate emulsion was used and, being of somewhat higher gravity, was more satisfactory, but still did not kill more than 40 per cent of the scale insects. Miscible oil No. 1 was next used, being of about 28° Baumé gravity. This used in a 12½ per cent solution was quite satisfactory, destroying from 75 to 90 per cent of the scale insects. A well-known washing powder was tried as an emulsifier with both the emulsion and the miscible oil, but proved of no value, so its use was discontinued.

Carbolic sheep dip was tried out, as this was reported to have very good penetrating powers. This, however, gave only about 30 per cent efficiency and was not used further. Six per cent was the highest used with this, as a higher percentage was believed to be dangerous to the tree. It also made the lungs of the experimenter quite sore.

Next, miscible oil No. 2 was experimented with, for this had the very high gravity of 33° Baumé. A 12½ per cent solution of this proved quite satisfactory, killing a high percentage of the scales and upon second application destroying virtually 100 per cent. Further experiments with this substantiated these results.

In Table II are recorded all spraying experiments performed upon the cypress bark scale. All spraying was done in the warm part of the day, generally in the afternoon, when the trees were dry. The spray was applied very heavily and thoroughly, every part sprayed being completely drenched. In experiments Nos. 19, 20, and 21 (small trees) the entire tree was sprayed; in all others only the trunk, lower limbs, and foliage were sprayed, as the trees were too large to be treated with a hand pump. The cypress foliage

appears to be very resistant, for no burning occurred at any time from the application of the spray.

It was discovered that the small larvæ were much more easily killed than the adult females. All larvæ could not be killed with one spraying, however, on account of the long period of hatching. The last of the brood were not hatched by the time the first were becoming adults; consequently two sprayings were necessary, one to exterminate the early hatched larvæ, the other to exterminate those hatched later.

TABLE II.—*Record of spraying experiments performed upon the cypress bark scale.*

No.	Date.	Formula.	Number of trees.	Per cent of efficiency.	Remarks.
	1918.				
1	Feb. 25	Crude-oil emulsion, 7½ per cent.	6	0	In shade.
2	Mar. 9	Distillate emulsion, 3 per cent.	3	0	Rained that night and following 3 days.
3	...do.	Distillate emulsion, 5 per cent.	5	0	Do.
4	Mar. 28	Distillate emulsion, 6 per cent.	4	25	In shade.
5	Apr. 10	Distillate emulsion, 7½ per cent.	3	20	Warm, dry.
6	...do.	Distillate emulsion, 7½ per cent, and washing powder, 1 pound to 20 gals.	3	20	Do.
7	Apr. 24	Distillate emulsion, 12 per cent.	2	40	Do.
8	June 4	Carbolic sheep dip, 3 per cent.	3	30	Hot, dry.
9	July 18	Carbolic sheep dip, 6 per cent.	2	30	Do.
10	Mar. 28	Miscible oil No. 1, 6 per cent.	4	25	Warm, in shade.
11	Mar. 29	Miscible oil No. 1, 6 per cent, and washing powder, 1 to 20.	3	40	Warm, dry.
12	Apr. 24	Miscible oil No. 1, 12½ per cent.	2	75	Do.
13	...do.	Miscible oil No. 1, 12½ per cent, and washing powder, 1 to 20.	2	40	Do.
14	Oct. 7	Miscible oil No. 1, 12½ per cent.	2	90	Warm, dry; repeat on No. 12.
15	...do.	Miscible oil No. 1, 8 per cent.	2	75	Warm, dry; repeat on No. 11.
16	July 18	Miscible oil No. 2, 12½ per cent.	2	75	Warm, dry; killed 50 per cent adults and 99 per cent larvæ.
17	Oct. 7	.....do.	1	75	Warm, dry; rained 2 days ago.
18	...do.	.....do.	1	100	Rained 2 days ago; repeat on 1 tree No. 16.
19	Oct. 26	.....do.	38	80	Hedge of young trees.
20	Oct. 28	.....do.	39	80	Do.
21	...do.	.....do.	1	85	Repeat on tree No. 38 of Experiment No. 19.

In experiments Nos. 1 to 7, percentages are of actual oil content, not emulsion content.

RECOMMENDATIONS FOR CONTROL.

The following measures are recommended for the control of the scale insect.

Cut out all dying trees or limbs of trees beyond saving and destroy them in order to reduce all possible sources of infestation.

Purchase clean nursery stock for planting. If the stock is infested, return it to the nursery and demand clean stock to replace it.

Most fruit growers now realize that spraying is necessary for the maintenance of healthy trees and the production of clean fruit. Most people, however, still believe that a shade tree should always be able

to take care of itself. One can not hope to maintain healthful, vigorous, shade and ornamental trees without proper care and occasional spraying.

Infested trees should be sprayed twice in the fall, once in August or the first part of September and again in the latter part of September. This is to kill the larvæ before they become mature. The proper dates to spray may vary slightly in different localities and with different seasons, in which case certain phenological events may be relied upon. The first spraying should be done when the fruit of the French prune (the common variety planted throughout the State) becomes blue or first begins to fall from the tree. The second spraying should be done from one to two weeks after the last prunes have been harvested. If but one application is attempted, spray in the middle of September or when the maximum number of prunes are falling from the trees, as this would be the best time to kill the greatest number of larvæ.

The only satisfactory material to be used is a 12½ per cent solution of a high gravity miscible oil (33° Baumé). The proportions are as follows:

	Part.
Miscible oil (33° Baumé)	1
Water	7

Put the requisite amount of oil in the pail or barrel to be used and add about one-fifth that amount of water. After some stirring this will become a thick creamy liquid, whereupon the remaining amount of water may be added with constant stirring. This should be continually agitated while being applied.

The ordinary barrel or bucket pump will serve very well in applying the spray to small trees. A good power apparatus, however, is necessary in order to compel the spray to reach to the top of large trees or to penetrate through the heavy foliage of thick hedges.

Thoroughness of the application can not be overemphasized. It is absolutely necessary for successful control. See that the spray comes in contact with every twig and that all the larger limbs and trunks are thoroughly drenched.

When planting trees not intended for trimmed hedges or windbreaks, leave a wide space between each individual. It is a common fault to plant all sorts of trees too closely. Cypresses planted purely for ornament should be fully 40 or 50 feet apart. Trees already planted can be thinned out to this distance. This will retard the spread of the insect and give more nourishment to each tree left. The addition of fertilizers and water about the base of infested trees will also aid in overcoming the effects of the scale insect.

In badly infested regions it is not advisable to replant cypresses. There are many other species of trees which are less prone to infestation and are just as ornamental, which should be planted. There are other trees and plants, also, which make effective trimmed hedges.

The common privet (*Ligustrum vulgare* Linn.) forms an admirable hedge. The holly-leaf cherry (*Prunus ilicifolia* Walp.), *Atriplex canescens* James, and *Pittosporum* spp. also are recommended. Pittosporum, however, is subject to attacks from scale insects which are just as difficult to control as the cypress bark scale. The Oriental and Italian cypresses form quite effective coniferous hedges, the latter being tall and slender. Certain forms of red cedar (*Juniperus virginiana* Linn.) are used as trimmed hedges in certain sections of the United States. If this proves to be immune to the scale insect, it should be a very good substitute for the Monterey cypress.

SUMMARY.

The main cause of the browning and death of so many cypress trees, hedges, and windbreaks throughout California is the cypress bark scale, *Ehrhornia cupressi.*

It was found in the course of a thorough investigation that the scale insect was not a native of the Monterey cypress, but of the incense cedar which occurs in the mountains of California, Nevada, and southern Oregon. From this host it has probably spread to the Monterey cypress by the transportation of incense-cedar seedlings or rustic timber to the regions infested.

The characteristic injury caused by this insect begins to show on one or two limbs and slowly spreads to the rest of the tree. The foliage turns first yellow, then red or brown, giving the tree a very dilapidated appearance. After a few years the whole tree dies.

The food plants of the cypress bark scale are Monterey cypress, Arizona cypress, Guadalupe cypress, and incense cedar.

The larvæ are small oval bodies, pale yellow in color, which are active for a short time after hatching. They attach themselves in crevices of the bark and are soon enveloped in a white cottony secretion. As they reach maturity they become reddish-brown in color and nearly spherical in shape.

Oviposition begins in the spring and lasts throughout the summer. The eggs hatch into larvæ in less than an hour and soon attach themselves. The females reach maturity in the fall and hibernate over the winter, starting oviposition in the spring. The males appear in the late fall or early winter to mate and die.

There are several insects which prey upon the cypress bark scale, none of which, however, is abundant enough to control the scale insect. Consequently remedial measures have to be adopted. A 12½ per cent solution of a high-gravity miscible oil is the spray recommended. To obtain complete control it is necessary to spray twice in the early fall, once in August and once in the latter part of September.

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BULLETIN No. 841

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. | PROFESSIONAL PAPER | May 7, 1920

THE WESTERN GRASS-STEM SAWFLY

By C. N. AINSLIE,[1] *Entomological Assistant, Cereal and Forage Insect Investigations*

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INTRODUCTION

The western grass-stem sawfly (*Cephus cinctus* Norton) (fig. 1) is in many ways one of the most interesting and important insects that has attracted the especial attention of economic entomologists in recent years. It is a species native to the United States and has been gradually coming into prominence since the beginning of the present century by reason of the change which the feeding habits of the larvæ have been undergoing subsequent to its discovery. Originally a grass feeder, it is becoming a serious menace to the grain growers of the Northwestern States because of its acquired appetite for small grains, within the stems of which it now subsists.

Such changes of diet are probably occurring everywhere with greater frequency than formerly was deemed possible, especially among the phytophagous insects of the Middle West. When given a

[1] The writer wishes to express his appreciation of the assistance afforded by Messrs. J. C. Crawford, A. B. Gahan, and S. A. Rohwer, of the Bureau of Entomology, in the preparation of this paper, the two former in determining parasitic material reared during the progress of the studies of the sawfly, the latter in making a critical examination of a large series of sawfly individuals reared or collected from various parts of North America, and for furnishing detailed descriptions of *Cephus cinctus* besides a key to the North American species of the genus Cephus. Helpful criticisms from these men have added to the value and accuracy of the paper.

The writer desires also to mention the valuable assistance and cordial cooperation of Mr. Norman Criddle, entomological field officer for Manitoba, Canada; of Mr. A. P. Henderson, of Bottineau, N. Dak., and of the several county agents in the infested areas, who have aided in various ways in the accumulation of information and material.

chance to feed upon the various cultivated plants grown in bulk by the farmer or gardener, many of these insects gradually desert their native host plants and to a greater or less degree change their habits, including in their fare the more succulent and easily found food.

HISTORY

The existence of the western grass-stem sawfly was first made known in 1890 when Mr. Albert Koebele reared adults from larvæ that were mining in the stems of native grasses growing in the vicinity of Alameda, Calif.[1] During the next year, 1891, the species was described under the name of *Cephus occidentalis* by Messrs. Riley and Marlatt, from a series of individuals reared by Mr. Koebele and also

FIG. 1.—Western grass-stem sawfly (*Cephus cinctus*): Adult female. Much enlarged.

from cotypes that had in the meantime been collected in Nevada and Montana.[2] In connection with this description the prophetic suggestion was made that: "The economic importance of this species arises from the fact that it may be expected at any time to abandon its natural food-plant in favor of the small grains, on which it can doubtless successfully develop."

Nothing more was heard of this sawfly until 1895, when the late Dr. James Fletcher, Entomologist to the Dominion of Canada, swept adults at Indian Head, Northwest Territories, on July 5. He believed it to belong to the European species, *Cephus pygmaeus* L., and under

[1] Koebele, A. Notes. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 3, p. 71, 1890.

[2] Riley, C. V., and Marlatt, C. L. Wheat and Grass Saw-Flies. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 4, p. 168-179, 1891. (See p. 177-178.)

this name it was mentioned in his report for 1896[1] with the further statement that wheat straws containing Cephus larvæ had been sent in by Mr. John Wenman of Souris, Manitoba, who stated that the injury done by them was very slight. Nevertheless the prophecy of five years before had been fulfilled, since these grass feeders actually had attacked small grain.

In 1902 Dr. Fletcher reported, in a private letter, that he had found the larvæ numerous in grasses in the Northwest. In 1905 and 1906 Mr. G. I. Reeves, an agent of the Bureau of Entomology, noted the work of the larvæ in various grasses, chiefly *Agropyron* sp., in Wyoming and the Dakotas, and in 1906 the same observer found the larvæ attacking wheat sparingly near Kulm, N. Dak.

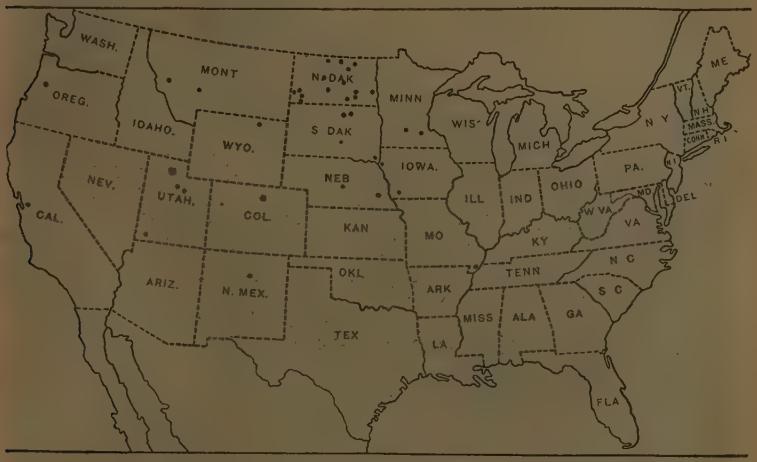

FIG. 2.—Distribution of the western grass-stem sawfly in the United States.

August 31, 1907, Mr. E. O. G. Kelly, then an agent of this bureau, noted a few wheat straws near Minot, N. Dak., that had been burrowed by the larvæ of Cephus.

In 1908 Messrs. F. M. Webster and G. I. Reeves found the larvæ of Cephus working in grasses in the Willamette Valley in Oregon. In the same year Dr. Fletcher again called attention to this insect, stating that in the previous autumn it had appeared in central Manitoba and in the southeastern part of Saskatchewan in much more serious numbers than ever before, and that the quantity of broken straws in the fields was causing the farmers some alarm. Mr. Norman Criddle of Aweme, Manitoba, a close observer and practical farmer, wrote to Dr. Fletcher that this fly had increased considerably during the last year or two, and was turning its attention to wheat and rye.

[1] Fletcher, J. Report of the Entomologist and Botanist, 1896. Can. Dept. Agr. Exp. Farm, 1897. (See p. 229-230.)

August 20, 1909, Prof. H. B. Penhallow reported from Sherwood, N. Dak., that he had examined about a hundred fields from Minot, N. Dak., north to the boundary line and several miles into Canada and had found larvæ present in every field but one. He estimated the damage in these fields as ranging from 5 to 25 per cent of the crop, but spoke of one field about 27 miles east of Sherwood where the damage was said to have exceeded 66 per cent. R. W. Sharpe reported similar damage in the Red River Valley, near Fargo, N. Dak.

During 1911 and 1912 the writer found the species occurring freely in the native grasses in various parts of Utah, and as occasion offered

FIG. 3.—Plants of *Elymus condensatus* growing along the railroad right of way. The natural habitat of the western grass-stem sawfly in Utah.

the life history of Cephus was learned. Most of the facts in this paper are the result of this study. (Fig. 3.)

During the years 1913, 1914, and 1915 the writer has found this sawfly almost universally distributed over the Dakotas, Minnesota, Iowa, and Nebraska, feeding in Elymus, timothy, and Agropyron at Elk Point, S. Dak., in *Agropyron tenerum* near Chamberlain, S. Dak., in timothy at Edgeley, N. Dak., in *Bromus inermis* near Merricourt, N. Dak., in *Elymus canadensis* at Shakopee, Minn., in practically all these grasses near Sioux City, Iowa, and in wheat, timothy, and Elymus near Minot, N. Dak. It seems to have little choice in the various native grasses and is ready to attack any of the cultivated

sorts provided the stem is sufficiently large for the larval gallery. As a rule, the larger, more robust stems are chosen for attack, especially in cultivated grasses such as timothy and Bromus. Blue grass and similar slender-stemmed species appear to be immune. It is a little surprising that a minute examination of *Stipa viridula* from New Mexico developed the fact that none of the stems of this robust grass were infested. This Stipa was gathered in northern New Mexico, growing in almost the same latitude as the *Elymus condensatus* near Pinto, Utah, where the fly abounds.

August 25, 1916, the writer, then at Pierre, S. Dak., received instructions from the Bureau of Entomology to visit Bottineau County

FIG. 4.—Wheat field of Thomas Yeam, near Souris, N. Dak., showing heavy damage done by the western grass-stem sawfly in 1916.

in North Dakota and investigate injury to wheat. It was believed locally that the Hessian fly was responsible for the damage that was being done. A very superficial examination of the injured fields proved beyond a doubt that the Cephus was present in large numbers and was doing an immense amount of mischief. Every field was infested, not only in Bottineau County, but in the adjoining counties of Benson, Pierce, McHenry, and Rolette. Near Souris, a few miles south of the Canada line, a large field of wheat on the farm of Thomas Yeam was fairly carpeted with the "straw-fallen" grain. (See figs. 4 and 5.) The loss from Cephus injury in this field was estimated at 60 per cent or more. Six feet of drill row here were taken at random and examined plant by plant. Forty-eight infested stubs were found,

an average of eight to each foot of drill row. This would mean 150 to the square yard or about 726,000 larvæ to the acre. Higher counts were made later in this same field, so the average may be larger than stated. During April, 1917, Mr. Yeam's field was again visited and a random square yard marked out and counted. Two hundred and sixty-nine infested stubs were taken from this yard, which would mean more than 1,300,000 larvæ to the acre. Fifty of these stubs were opened and 47 of the imprisoned larvæ that had spent the winter within the straw were found to be normal and very much alive. The proportion of living individuals among the hibernating larvæ seldom falls below this ratio.

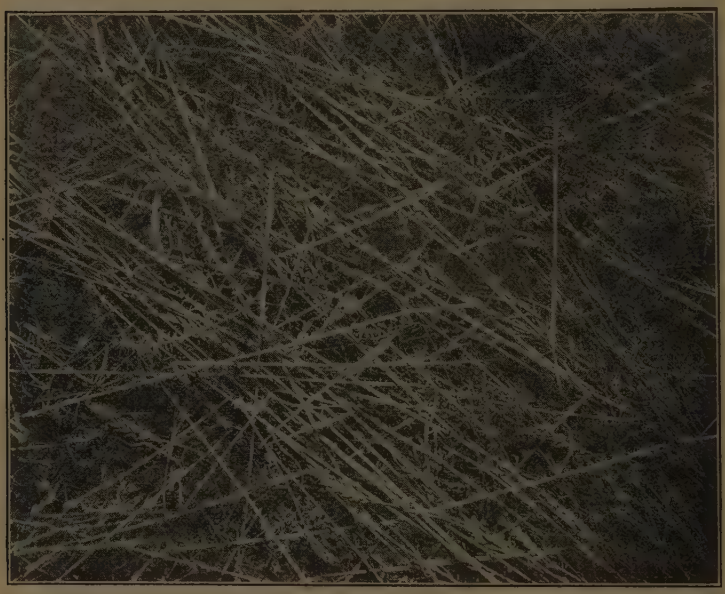

FIG. 5.—Bird's-eye view of wheat in Thomas Yeam's field, Souris, N. Dak. Ninety per cent of these fallen wheat stems have been mined by the western grass-stem sawfly.

The spring of 1917 witnessed a peculiar condition of things in Bottineau and the adjoining counties of North Dakota. The dry weather hindered the growth of both grasses and grains, so that when the adult Cephus began to appear in June there was almost no opportunity for oviposition. Stems of Bromus from chance sods growing among wheat and on waste ground were filled with eggs. Young plants of spring wheat that had barely begun to joint were attacked and often contained as many as three and four eggs placed in the stem close to the ground. With a few strokes of the net 136 adults were swept from young wheat, so numerous were the flies at that time. In spite of the unfavorable oviposition conditions of that spring, the

eggs appear to have hatched and at harvest time the majority of the wheat stems had been bored and many were cut off at the base. Careful harvesting and the use of horse rakes saved a large proportion of what otherwise would have been a total loss. The infestation was much more general than in 1916.

A somewhat hasty reconnaissance was made through north-central North Dakota in August, 1919, that it might be ascertained as definitely as possible just how the Cephus attack was progressing. A number of fields in Bottineau County were examined and found to be heavily infested. Most of these had been raked after harvest and it was consequently impossible to compute accurately the percentage of infestation. The numerous sawfly-inhabited stubs in the drill rows, however, proved the severity of the attack. It was roughly estimated that about 30 per cent of the grain had gone down in most of these fields as the result of Cephus work. This figure is probably very conservative.

It is conceded by many observers in that region that the injury during the year 1919 was greater than during any previous year since the study of this pest was begun. More fields had been seriously invaded and were injured to a larger extent than had before been observed. Even fields of durum wheat, hitherto believed to be nearly free from fly attack, were severely injured in 1919, if the statements of reliable farmers are to be accepted. The question of immunity of durum wheat will be discussed later in this paper.

It may be stated, however, that the farmers are profiting by past experience and have used horserakes in stubble fields to such an extent that the percentage of actual loss of grain has been reduced to a small figure. The quality of grain from the fallen straw is naturally somewhat below the normal, since the work of the larvæ in the stems produces some injury in the heads as they fill.

Cephus was found mining wheat near Hettinger in southwestern North Dakota, July 18, 1917. September 22, 1917, infested wheat was found near Mott, 30 miles north of Hettinger. In October of the same year many wheat fields in Towner and Cavalier Counties, in northeastern North Dakota, showed heavy infestation, although during the previous year it was difficult to discover more than a trace of Cephus presence in the wheat in this region. None was found in the vicinity of Fargo, although it doubtless occurs throughout the entire Red River valley.

A gathering of sods of *Elymus canadensis* sent to the writer from Charleston, Mo., during the summer of 1917 contained at least one larva of *Cephus cinctus* that had been boring the stem of this grass in that region. This locality is a little south of the latitude of Pinto, Utah, where this insect abounds.

Roughly speaking, so far as is now known, the sawfly inhabits an area bounded on the north by a line far into Canada; on the east by the Mississippi River, or probably a little east of that; on the south by latitude 36°; and by the Pacific Ocean on the west.

From the foregoing brief summary of its history it will be seen that *Cephus cinctus* is distributed over an immense territory and that it constitutes a potential menace to the small grains throughout this vast area. As the acreage of native grasses is decreased from year to year by the bringing of wild lands under the plow, pests such as the sawfly will be forced to depend in an increasingly large measure upon the small grains and other products of the farms. On this account the injury caused by these formerly harmless insects bids fair to increase steadily. In the past the numbers of grass-feeding insects such as the one considered in this paper have been governed mainly by the supply of food plants. A dry summer that retarded the growth of long-stemmed grasses would automatically reduce the numbers of the insects that lived within these grass stems and perhaps bring certain species to the point of extinction. It is easy to see how seasonal fluctuations in vegetation would, to a large extent, either multiply or diminish the numbers of these insects.

Then again, the farmer, by introducing fields of grain into a region previously uncultivated, brings in conditions unknown before and invites the attack of these and other formerly harmless insects, making it possible for them to become a menace to his future. Such a study of life history as has been attempted in this paper is urgently necessary in order that control measures may be undertaken successfully when such insects become pests.

FOOD PLANTS

The various species of Agropyron and Elymus, genera both of which are well represented in the West, appear to have been the original hosts of the larvæ. Since their feeding habits have been modified by changing agricultural conditions, the list of their present host plants, so far as known, stands as follows:

Elymus canadensis	*Agropyron occidentale*	*Calamagrostis* spp.
Elymus condensatus	*Agropyron caninum*	*Festuca* sp.
Agropyron tenerum	*Hordeum jubatum*	Wheat
Agropyron richardsoni	*Bromus inermis*	Durum
Agropyron smithii	*Phleum pratense*	Spelt
Agropyron repens	*Dendrapsis* sp.	Rye

Barley probably should be added to this list.

Since the larva is wholly unable to move from one stem to another, it is very obvious that the host stem must be large enough to afford both shelter and food during its entire growing period. Hence only the larger-stemmed grasses can be mined successfully by the Cephus

larvæ. Occasionally an unusually vigorous plant of a slender-stemmed grass, like *Hordeum jubatum*, affords stalks with diameter sufficiently great to be attacked by Cephus.

Small grains, such as wheat and rye, readily serve as hosts to this insect, because they are of suitable size and the length of their growing season coincides with the growth of the larva. Even if harvest time should happen to come before the maturity of the larva, the reaping machine probably would sever the stem far enough above ground to leave the larva below the sickle cut, where it could house itself safely before the end of the season.

Judging the future by the recent past, it seems probable that this fly, before another decade is past, will be found attacking practically all of our native and cultivated grasses and most of our grains.

It must be remarked in this connection that up to the present time this species has confined itself entirely to the West and has been found in only a few localities east of the Mississippi River. Its choice of wheat for food has taken place, so far as known, only in North Dakota and western Canada, although it is probable that Montana wheat fields have been invaded. From present appearances its attacks probably will be confined to vegetation growing within the area where spring wheat is sown.

THE EGG

The egg of *Cephus cinctus* is, when newly laid, decidedly crescent-shaped, glassy in appearance, milky-white in color, usually quite symmetrical, the ends of the crescent tapering and rounded. It is marked by very faint, short, longitudinal lines or wrinkles, placed without regard to order or pattern.

The size of the egg varies with the size of the female that produced it and measures from 1 mm. to 1.25 mm. in length. The greatest breadth is about one-third the length.

The covering membrane is hyaline and transparent. Although very thin and delicate it is sufficiently strong so that the egg may be safely lifted and moved by the aid of a fine brush. The egg always lies free within the stem of the host plant, either in the stem cavity or in a hollow excavated by the ovipositor of the female that placed it. This cell is always a little larger than the egg, so that it is comparatively an easy matter to remove the egg to a moist cell or elsewhere for study.

The number of eggs distributed by each female appears to vary but little. Dissections of a number of adults taken in the field and of others reared in captivity agree in most cases in giving a count of about 50 eggs in the ovaries, these eggs being, as a rule, equal in size and apparent maturity.

DEVELOPMENT OF THE EGG

After a number of trials it was found to be impracticable to rear the egg *in situ*, since it was next to impossible to maintain the proper moisture conditions within the stem. The method that finally was adopted, and that gave excellent results, was to remove the egg from the stem and place it in a minute drop of water within a small thin watch glass which was then immediately inverted on a glass slip and sealed with a ring of water to prevent undue evaporation. This form of moist cell proved quite satisfactory and permitted continuous examination of the egg with a moderately high-power lens during the entire period of incubation. It was found necessary, in order to continue the requisite moisture supply during a period of several days, to invert over the sealed cell a larger watch glass and over this in turn a tumbler. In this manner evaporation was reduced to a minimum. It is altogether probable that the amount of moisture in such a protected cell exceeded that normally present within the grass stem, but in every egg treated in this way the incubation appeared to proceed naturally.

Temperature and moisture are, without any doubt, the prime factors that hasten or retard the egg development. The temperature maintained within the laboratory during the course of these investigations was much more equable than that in the field, where, as in Utah, the heat of the sun through the daytime, followed by a chilly night, must alternately hasten and check development. The data given below, therefore, may only approximate what actually takes place under field conditions.

A few hours after the egg leaves the oviduct the milky-white contents of the egg which at first completely filled the envelope shrink a little from each end leaving a transparent space or vacuole. Gradually the interior mass of exceedingly minute particles coalesces until about the second day when a series of faintly discernible cells arranging themselves along a central axis begins to appear. Early on the third day the form of the larva can be dimly seen, the head being almost transparent and filling one end of the egg sac. The body is looped on itself, the cauda folded beneath the abdomen and extending forward nearly to the head. By the close of the third day the abdominal segments are usually well defined.

During the fourth day, in most cases, a spasmodic and intermittent heart beat may be noticed. These pulsations become more and more regular as the hours pass and during the fifth and sixth days the heart beats with much regularity at the rate of about 120 impulses per minute. At intervals, for some unknown reason, it may slow down to 75 beats, but soon resumes its former rate.

The head appears abnormally large at this time, but although its general outlines are well defined the brown jaws and eye spots are

not yet visible. Over night, at the close of the fifth day, the jaws turn brown and the eye spots appear and darken. Usually, after the fourth day, the muscular system of the larva is in almost constant motion, shifting and adjusting, with the heart pulsating and the muscles moving, all clearly to be seen through the transparent membrane that serves as the shell.

The activity of the larva within the sac increases during the sixth day, and either on this day or the seventh it escapes from its confinement by a series of convulsive movements that rupture the delicate shell and set it free.

After the first day the egg changes shape, becomes intumescent, generally loses its crescentic shape entirely, and grows oval or reniform in outline.

THE LARVA

When it escapes from the egg the larva (fig. 6) possesses a very large head armed with a pair of powerful biting jaws, a weak, slender body, and a most vigorous appetite. It is very active from the start and begins almost at once to feed upon the living parenchymatous tissue by which it is surrounded in the interior of the stem, excavating for itself a threadlike gallery both above and below the spot where the egg formerly lay. The larva is at first nearly transparent and colorless until it becomes filled with the tissue on which it exists.

FIG. 6.—Western grass-stem sawfly: Newly-hatched larva. Greatly enlarged.

The body segments are strongly and clearly marked from the time the larva leaves the egg. The jaws are brown, three or four pointed, the points chisel-shaped, beveled on the inside edge. The brown face plate is filled with crossed bands of striated muscular fiber that actuate the powerful jaws which form the most important item of the domestic economy of the young Cephus. The caudal horn, by means of which the larva moves up and down in its gallery, is also brown and is armed, even in the first instar, with a series of stout bristles at the base of its cylindrical and squarely truncate extremity. The larva is footless, the position of the legs being marked by minute, rounded tubercles terminating in a few short bristles.

Although the primary excavation made by the larva may extend for a short distance above the egg cell, the general course of the progress is invariably downward. In its earlier stages of existence, at least, the larva traverses its gallery several times, swallowing repeatedly the same fragments of tissue that have already been devoured during the first excavation of the stem. Young larvæ are

frequently found several inches above the lower end of the boring, moving through the solidly packed "sawdust." As the larva approaches maturity it is doubtful if it ventures into the upper and slender part of the stem, but it still reworks the frass farther down, enlarging the bore in places.

The number of instars is difficult to determine, owing to the larval practice, just referred to, of passing all the frass several times through the digestive apparatus. Nearly all the cast skins disappear completely under this treatment, only the heavily chitinized parts such as the jaws and caudal horn being recognizable in the burrow. Care-

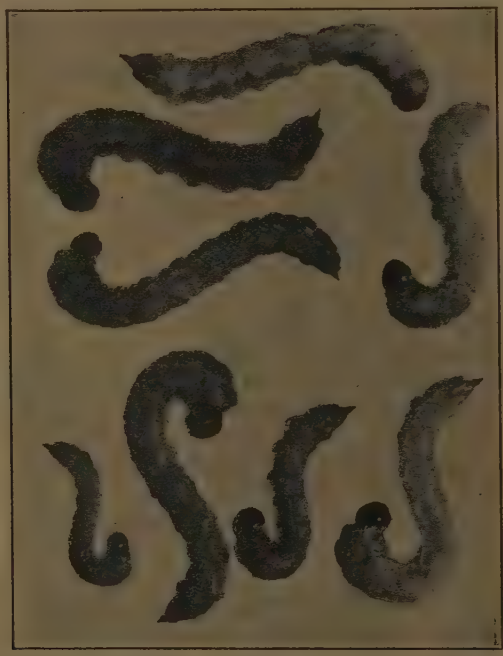

FIG. 7.—Western grass-stem sawfly: Mature larvæ removed from their galleries. Enlarged 4 diameters.

ful investigation of these fragmentary remains appears to establish the fact that there are four molts. The contents of innumerable stems have been examined with scrupulous care and with varying results. In a few cases as many as four sets of jaws and in others four caudal horns have been found, mixed with the frass within the stems. Seldom were more than four sets removed from a single stem; usually only three were found. As is stated elsewhere in this paper, it is no uncommon thing to discover two and even three larvæ mining a single stem, although but a single individual can possibly reach maturity with the amount of nutriment contained in

one stem. It is believed that the larva that finally reaches maturity has devoured its rivals. It is obvious that the remains of these superfluous individuals would naturally be counted when a census of exuviæ was undertaken and would complicate the result. But from the best evidence obtainable it is almost certain that there are five instars in the larval life of this species.

The length of the larval period is probably about 60 days, varying more or less with the warmth of the summer and the state of maturity of the host stems. The acceleration or retardation of the oviposition period owing to an early or late spring has much to do with the date of maturity of the larvæ, and possibly with the length of the larval period. August 29, 1911, at Kimballs, Utah, at an elevation of 7,000 feet, the writer found mature larvæ in stems of *Elymus condensatus*. The next year, at the same place, oviposition was beginning freely during the first week of July. The determination of the larval period is wholly inferential, based upon the findings in a series of stems (figs. 7 and 8).

The full-grown larvæ vary greatly in size, their growth being governed, as is usual in the case of such borers, by the quality and quantity of food consumed. Those living in wheat stems are much smaller as a rule than those found in rank-growing grasses such as Elymus. Measurements of a series of individuals give variations of from 8 to 14 mm. in length and from 1 to 2 mm. in diameter.

FIG. 8.—Western grass-stem sawfly: Mature larva. Enlarged 5 diameters.

When mature the larva always seeks the extreme base of the stem, where it soon begins its preparations for hibernation. Its first move is to cut a neat V-shaped groove entirely around and inside the stem, usually at or a little above ground level. This groove never severs the stem completely, but so weakens it that the upper stalk, swayed by the wind, will break off completely when dry, leaving a stub that is very characteristic of the work of this insect (fig. 5). In this simple manner the larva provides for the easy escape of the adult in the following summer. The length of the stub thus formed varies greatly. In *Elymus condensatus* the stub sometimes will project above the ground as much as 3 or 4 inches, while in other grasses, and especially in wheat, stubs easily can be found less than an inch in length in all.

Instances have been observed where two or more grooves had been cut inside the same stem, as if the larva had been uncertain as to the best place for severing the grass. After cutting its characteristic groove within the stem the larva forces a mass of the débris into the

bore just below the groove and in this manner plugs the upper end of the stub that is to be left in the ground after the upper stalk has been broken away (figs. 9, 10, and 11). This dry frass in some manner is packed firmly into its place, perhaps by means of pressure rather than by being cemented with a liquid furnished by the larva, since the plug is readily penetrated by moisture. This is somewhat remarkable in view of the fact that an undue amount of moisture appears to have a disastrous effect upon the mature larva. One would suppose that these stubs, often wholly submerged in water-soaked earth for weeks at a time, would absorb, during the long period of hibernation, a fatal amount of dampness from the rain or melting snow. But there is no evidence that this ever happens.

FIG. 9.—Western grass-stem sawfly: Infested wheat stubs from Bottineau County, N. Dak.

September 16, 1911, one of the larvæ was removed from the hibernation chamber and placed in a small vial, still inclosed within the silken tube or cocoon, which was unbroken. For months this larva remained passive and motionless except when the vial was exposed to bright sunshine. Because of the light or heat, or both, when placed in the sunlight it would become active at once, and travel up and down within its cocoon in its efforts to escape. January 20, 1912, to prevent the air in the vial from becoming too dry a small drop of water was introduced and the vial again corked tightly. An hour later it was noticed that the silk tube had collapsed and the larva within was limp and apparently dying. The surplus moisture was removed quickly, whereupon the larva revived almost at once.

If the same amount of moisture had entered the stem where the larva was hibernating it probably would have caused its death. This experiment, taken in connection with others that were not so directly conclusive, seems to prove that the porous plug in the stub must prevent in some way the admission of an undue amount of moisture into the chamber below, although water readily penetrates it.

The gallery below the plug is always entirely free from débris, forming a hibernation chamber and later a pupation cell. Within this chamber the larva lies with its head up and usually pressed against the barrier at the top, always on the alert to retreat downward at any sign of disturbance. It descends by alternately flexing and straightening the body, bracing itself first by the jaws, then by the caudal horn as it hitches its way down In ascending, the caudal horn is thrust against the side of the gallery or the cocoon, the body is straightened, the jaws obtain a purchase to hold the distance gained, when the body is again drawn up until the caudal horn is applied to the side wall for another push.

FIG. 10.—Western grass-stem sawfly: Infested wheat stubs, enlarged 3 diameters, the two left-hand ones opened to show hibernating larvæ *in situ*.

Late in the summer or during the autumn the larva spins for itself within the hibernation chamber an almost transparent tube of filmy silken tissue. This silk tube is sometimes several times the length of the larva, is closed at both ends, and is free from the sides of the chamber, so that often it can be readily withdrawn entire. When first constructed this fabric is comparatively strong and pliant but after some months it grows more brittle and is easily ruptured. As a rule it remains intact until the emergence of the adult. Even the presence of half a score of parasitic larvæ often fails to wreck the delicate structure during the winter.

The longevity of the sawfly larvæ is remarkable and is worthy of mention. September 8, 1911, a number of stubs of *Elymus condensatus* containing Cephus larvæ were gathered and set upright in sand within doors. From time to time this sand was moistened but finally was allowed to stand perfectly dry. During October, 1912,

these stubs were examined and a number of the inclosed larvæ were found to be still living, active, and unchanged. Four months later, 17 months from the time they were gathered, they were still alive and feebly active. Infested stubs of the same grass taken during September, 1912, and treated in the same manner, contained at least one living larva on February 23, 1916, 3 years and 5 months later. The others had nearly all died within about 30 months of the time they were gathered. It is possible that the lack of necessary moisture may account for the retardation of these captives. However, the same retardation of development has been noted in the field. Inhabited stubs of the previous year's growth of grass and grain not infrequently have been found, containing larvæ that were to all appearances entirely normal and active. It appears more than probable that in this manner the perpetuation of the species is assured in case of unfavorable seasons.

FIG. 11.—Stems of wheat grooved internally by larvæ of the western grass-stem sawfly.

During the winter the larvæ are, of course, frozen, or are chilled into immobility and show no signs of life when disturbed. As soon as the earth warms in the spring they again grow active and move freely up and down within the limits of the silk-lined hibernation chamber until the time of pupation arrives.

THE PUPA

The pupa when first formed is milk-white, slender, and somewhat longer than the larva from which it was derived. Its average length is not far from 12 mm. and its breadth is about 1.5 mm. At first the pupa lies motionless within the silken pupation chamber or cocoon (fig. 12) for probably a day or two, after which inactivity it again becomes animated. When disturbed it will endeavor to escape the threatened danger by moving either up or down the tube, hitching itself along in much the same manner as the larva but going a lesser distance with each effort. Like the larva it is almost always found with its head pressed closely against the plug of frass at the upper end of the chamber. In a few cases pupæ have been discovered heading downward in the stem. It is doubtful if these can reverse

their position, but the adults which issue are probably agile enough to turn about and escape.

The duration of the pupal period is not known certainly, but is believed to be very brief, not more than a week at the most. After the first day the legs and body darken until they become a lustrous black within the transparent, almost invisible filmy membrane in which they are inclosed. This membrane is often lacking and may occasionally be destroyed by the movements of the pupa within the chamber.

When fully mature the pupa changes within the cell to an active adult. This adult remains imprisoned until some unknown impulse compels it to force its way upward through the plug of frass placed at the upper end of the chamber by the larva 9 months before. The writer, by splitting stubs of grass or grain in June, has liberated adults repeatedly, which, when free, were able to take instantly to wing without any preliminary process of drying or other preparation. These adults were evidently resting, in perfect condition, waiting for some secret signal from the outside world before taking the final step for liberation.

A very few die within the cell, possibly because of lack of vitality needed to break through the stopper of frass above them. In cases where the girdling of the stem was inefficiently done, so that the grass stalk did not break off during the winter season, the adult dies as a matter of course, since these flies apparently are not fitted with jaws capable of biting through the woody stems of dry grass.

FIG. 12.—Western grass-stem sawfly: Pupa. Three and one-half times natural size.

THE ADULT

The adult *Cephus cinctus* is a beautiful insect with a polished black body marked by three prominent yellow bands across the abdomen. The legs are yellow and the wings smoke-colored.

The description, by S. A. Rohwer, follows:

Length 7 to 12 mm. Head shining, polished; anterior margin of clypeus truncate with angles prominent and sometimes slightly denticulate; antennæ usual for the genus; thorax shining but with setigerous punctures on scutum; sheath nearly parallel-sided but a little broader at base, apex truncate with corners rounded; hypopygidium rather narrowly subtruncate apically. Black marked with bright lemon yellow, amount and extent of yellow markings varying greatly; head of female usually black but more rarely with face entirely yellow or having yellow spots; head of male black but always with yellow on face; thorax black, the upper angle of mesepisternum, parapteron, and scutellum (usually) yellow; legs yellow with coxæ, trochanters (occasionally both of these having yellow marks), bases of femora more or less, apices of tibiæ and tarsi sometimes, black; hind tibiæ and tarsi sometimes reddish yellow; abdomen black, spot or band on second tergite, band on third, fifth, sixth, and eighth

tergites and lateral margins of tergites yellow, the size and extent of these markings varying and occasionally the fourth tergite having a yellow band; wings fuliginous, venation dark brown, costa and stigma yellow.

The female is noticeably larger than the male, and in the field is captured much more easily.

The characteristic attitude of the adults of either sex while at rest is to lie flat against the grass stem, head downward, the body closely appressed to the stem, the legs not spread but stretched in line with the body while the body itself is concealed behind the closely folded, smoke-colored wings. The ease with which such a strikingly colored fly, while in this position, can escape observation, is remarkable. During the chill of the morning and after sundown this attitude is universally assumed. When basking in the sun at midday, on the warm side of a grass stem, the fly is much less compact, with the wings partly spread and the legs outstretched in order to absorb the utmost of the warmth. Like most Hymenoptera, this species is very partial to sunshine and rarely is seen abroad on a cloudy day. In fact, in cloudy weather it is not easy to find these flies at all, unless one is entirely familiar with their habits.

They are weak fliers and seldom travel to any great distance at one time. In Utah they commonly move about among the plants of bunch grass, making short flights from tuft to tuft. If the wind rises or the sun goes behind a cloud they promptly disappear until conditions again become satisfactory. The writer has never taken the adults at any great distance from their breeding places.

Their hovering flight is peculiar, the swaying motion of their bodies in the air reminding one of certain tipulid flies during their mating air dance. They often hover for a long time to the windward of a grass plant without alighting, seeming to enjoy the motion. The males are on the wing much more than the females, but neither sex will remain in the air while the wind is strong or when it is cool. The adults are not at all timid and can often be readily taken from the grass stems with the fingers. When conditions are favorable for her the female is usually too intent on oviposition to be easily annoyed but if disturbed beyond endurance she quickly disappears, her dark color and slender body enabling her to vanish completely among the vegetation.

Copulation is very brief, usually lasting less than a minute. No notes were made on the attitude assumed during the operation.

The species is single brooded, the adults appearing during the spring and going out of existence some time about midsummer.

The earliest individual met in Utah was taken in a net April 26, 1910, in an alfalfa field. Adults have been seen in the mountains late in July and they probably linger longer than that, ovipositing in such green grass stems as they can find. Near Kimballs, in Utah, September 8, 1911, the writer took very young larvæ from stems of

Elymus condensatus, growing from plants that had been browsed by cattle and had thrown up fresh green stalks.

Mr. Norman Criddle states that in Canada the adults appear during the second week in June and may be met with until about July 10. Occasionally they may be found feeding on flowers. Doctor Fletcher has taken them in Canada on flowers of the tumbling mustard. It is unquestionably true that the time of their appearance and the length of adult life are both largely governed by climatic influences and vary with the season.

When confined in emergence tubes or other limited places the males develop savage instincts and attack each other without mercy, using their jaws freely to snip off the antennæ, and, in some cases, the legs of their rivals. Singularly, very few of the females confined with them are thus mutilated.

OVIPOSITION

Weather conditions have always been an important factor in controlling the oviposition of very many of the Hymenoptera, and they are of particular importance in the case of the Cephus. These flies go into hiding when the day is dark, damp, cool, or windy. Only on bright, warm, still days are they to be found busy with the operation of placing their eggs. In Utah, where the first studies of their habits were made, the mornings and evenings are chilly as a rule, hence the activity of these flies is confined to the hours near midday. They are everywhere the most active between the hours of 10 a. m. and 2 p. m.

The swaying of the grass and grain stems in the wind appears to be a hindrance to them in alighting and ovipositing. A gentle breeze will often keep them hovering for several minutes to the windward of their goal, while a sudden mountain gust is apt to put an abrupt end to all efforts for the balance of the day. Their actions are controlled by unknown factors, for sometimes on a still, sunny day they will spend much of the time roosting on the stems, while again, under apparently the same conditions, they are constantly in motion, flying and hovering a long time before alighting.

While the female is poised in the air before a sod of grass or grain she is evidently busy selecting the particular stem in which she hopes to oviposit. Once she has chosen and settled, she seldom changes to another stalk, although she may halt at several places on a single stem and attempt oviposition at each pause. Occasionally, after a hasty examination, she may again take to wing and make another choice. Repeated observations seem to have established the fact that one of the chief requisites of a proper stem is that it shall not yet have put forth a head. In all the countless instances where oviposition has been observed, the female has never been known to choose a stem with a head.

When she has made her selection of a suitable stem, the female usually alights about half way up and runs briskly to the upper end, halting almost imperceptibly every few steps. The gait of an ascending fly is so characteristic that it determines with much certainty if the individual is a female intent on oviposition.

FIG. 13.—Western grass-stem sawfly: Female ovipositing. About life size.

Arriving at the apex of the stem, after a careful survey of its condition, she frequently makes an elaborate toilet, preening herself most carefully, until she is in perfect condition. She then descends, exaggerating slightly the hesitating step by which she had ascended. The antennæ are held horizontally in front of the head as she moves, and she occasionally touches the surface of the stem with their tips. There is none of the rapid antennal vibration so common among the smaller chalcids and many other Hymenoptera. She gives no evidence of being in search of any particular point, but goes straight down the stem. When satisfied that she has gone far enough she halts abruptly, usually an inch or less above the second node from the top of the stem, slowly arches her abdomen and clasping her hind pair of feet around the stem as far as they will reach begins to drive the saws into the hard outer tissue. Figure 13 shows the attitude taken at this time. These saws are exquisitely fashioned, curved like a scimitar, double, very thin with serrated edges. (See fig. 14.) They are used to split the outer coating of the stem rather than to cut it, and they make an opening so exceedingly small that it is almost impossible to find the scar after the wound has healed. These saws are gradually forced into the stem, the operation occupying a minute or more. In the field the female always heads downward during oviposition and the curve of the saw blades brings them, when fully inserted, in a line parallel to the axis of the stem. They are frequently partly withdrawn and their direction slightly changed. When the stem is in proper condition the saws are thrust in several times, as far as they will go, then are withdrawn,

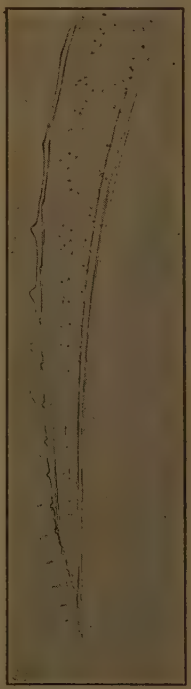

FIG. 14.—Western grass-stem sawfly: Saws, greatly enlarged.

the dorsal part of the pygidium being used as a fulcrum to extract them. They are inserted again, this time often with a twisting motion as if trying to enlarge the opening. They are finally forced in as far as possible, as is evidenced by the tenseness of the rear legs straining at the stem, and are held in this position for half a minute or more. This is probably when the egg is deposited, the insect standing practically motionless except for a slight vibration of the antennæ.

A laboratory note may be of interest, giving in detail some of the facts that have been mentioned above:

June 5, 1912. The adult Cephus were emerging freely from the Elymus material brought from the mountains, and it occurred to me it might be possible to secure some views with the camera if they could be induced to oviposit. Several females were observed attempting oviposition in the dry stems from which they had recently emerged.

A green stem of Elymus was planted in a tumbler of wet sand and the camera focussed on this stem about midway. After a few trials I discovered that this stem must be short and headless.

The females were taken from the cage and placed, one at a time, on the damp sand in the tumbler. Their first act in every case was to spend a long while drinking eagerly of the water held in suspension by the sand. A few of them sipped water for as much as half an hour before they could be induced to leave. When guided to the base of the Elymus stem they would usually ascend without a moment's hesitation. Once started they would go to the very top and there would either preen themselves interminably, or would wheel and descend with the usual cautious, hesitating gait, a few steps at a time. When part way down, without apparently choosing any especially suitable spot, the abdomen would arch and oviposition would begin. Sometimes these efforts were plainly failures, but some of the flies would sink their saws well into the tissue of the stem and stand for a number of seconds motionless, thus affording an opportunity for the camera.

Much time was lost to-day because of the exasperating neatness of these insects. Each one would brush herself over and over again with the most minute exactness and no amount of urging would avail to shorten the process. The same careful preening has been frequently observed also in the field.

Several life-size views of these flies were obtained to-day by the above method, views that would be impossible in the field because of the almost constant motion of the limber grass stems. Several of the females became confused to-day when compelled to remain on a certain part of the grass stem during oviposition, and faced up the stem instead of down as they invariably do, normally.

When busy with oviposition they seem oblivious to whatever is going on around them, and the writer has repeatedly watched, through a half-inch triplet, the female manipulating her saws. Close observation did not annoy her in the least when the lens was carefully handled, and she paid no attention to the proximity of the onlooker. Under the closest scrutiny it is impossible to determine just when the egg is passed into the stem. It is probably at the time when the female stands motionless after the saws have been driven in to their full length.

The function of these saws appears to be twofold. At Pinto, Utah, in June, 1912, the writer found that the eggs were invariably placed

in a cell hollowed in the solid parenchyma of the stem of *Elymus condensatus*, this cell being a little larger than the egg. Besides piercing the stem, the saws are also of use in excavating this egg cell, in case such a cell is needed. At Kimballs near Salt Lake City, in the same grass, the eggs were nearly always placed in the hollow part of the stem, lying free in the central cavity.

Normally but one egg is placed in each stem. However, no attention is paid to previous oviposition and as many as five eggs have been taken from a single stem. As is stated elsewhere, only one of these larvæ can possibly survive until fall, so this multiplication of eggs simply means economic waste for the Cephus.

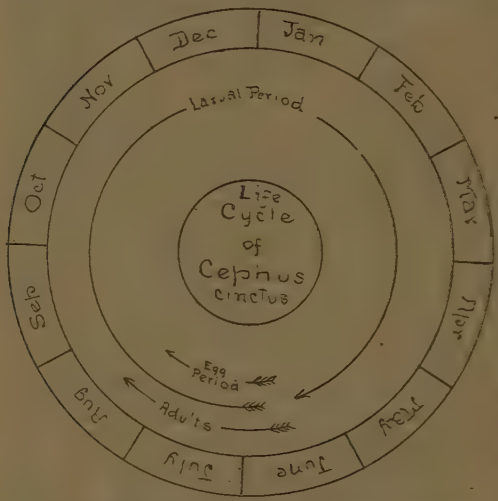

FIG. 15.—Life-history diagram of the western grass-stem sawfly.

The date of oviposition varies with the latitude and the altitude. At Pinto, Utah, on the edge of the desert country and with a low altitude, newly hatched larvæ were found June 14, 1912, while at Kimballs, 350 miles north of Pinto and with an altitude of 7,000 feet, oviposition was beginning during the first week of July in the same year.

Mr. Criddle states that in Canada most of the eggs are deposited during June. The date of oviposition in the Dakotas and in Minnesota is unknown. (Fig. 15.)

KEY TO THE NORTH AMERICAN SPECIES OF CEPHUS

Through the courtesy of Mr. S. A. Rohwer of the Bureau of Entomology a key for the determination of the known species of the genus Cephus occurring in North America is here presented.

Stigma and costa dark brown of a uniform color; mesepisternum black; femora black; apical tergite and venter black; face and scutellum black; face of male with yellow spots ..... *pygmæus* Linnæus.

Stigma in greater part and costa yellow; mesepisternum with the upper angle yellow; apical tergite and usually the venter in part yellow; femora usually mostly yellow; face and scutellum of female usually black but occasionally with yellow spots ..... *cinctus* Norton.

NATURAL CONTROL

In the usual scheme of things an undue increase of insect pests is controlled naturally by parasites that take a heavy toll of their hosts and prevent their multiplication. Under normal conditions, when the *Cephus cinctus* existed wholly in grass stems, the larvæ were attacked with varying success by two or more species of parasites that destroyed numbers of them and kept them within reasonable bounds. Since the fly has begun to change its habits and to subsist on wheat and other small grains to a certain extent, these parasites apparently have not yet learned of the change and are confining their attacks, as heretofore, almost entirely to those larvæ that they find in grass stems. A very few parasites have been taken from infested wheat stubble, and there is little question but that in course of time the busy little parasites will hunt their prey in the grain stems and do their share in helping to control this pest.

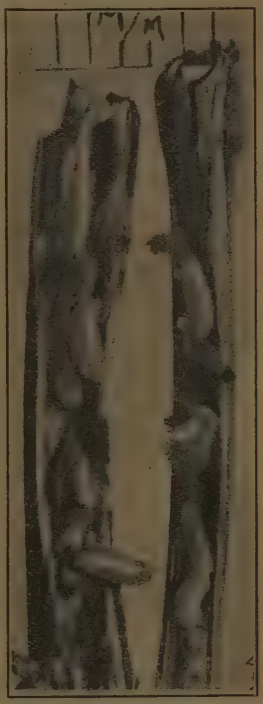

FIG. 16.—Larvæ of *Pleurotropis utahensis*, a parasite of the western grass-stem sawfly, *in situ*.

The most common parasite found everywhere in the grasses is *Pleurotropis utahensis* Cwfd., a beautiful little bronze-green chalcid that was reared by the writer from numerous larvæ taken near Salt Lake City, Utah, from Cephus hibernation cells. This species appears to kill the larva only after it has formed its hibernation cell. It is gregarious and seldom or never attacks its host singly. As many as 12 of its larvæ have been taken from a single cell, but 5 or 6 is a more common number. These larvæ are white and measure from 2.5 mm. to 3.5 mm. in length. They are somewhat active and travel slowly about the cell when mature. They are often found crowded together in one end of the cell, but when disturbed will scatter about the chamber (fig. 16).

Although this species is widely distributed and propagates in numbers it appears to destroy but a small percentage, possibly 10 per cent of the Cephus larvæ in the native grasses of Utah. In Bottineau County, N. Dak., it attacks the sawfly very freely in Bromus and timothy, and in some localities has killed more than 50 per cent of the Cephus larvæ. Indeed, it and one other parasitic

species are so numerous in these roadside grasses that it would seem poor policy to recommend the cutting of the grasses in midsummer as a measure of Cephus control. As has been stated, few parasites have been found in stems of wheat, but, without doubt, they will learn very soon of the presence of Cephus in grain fields and will adjust their habits accordingly.

A braconid, *Microbracon cephi*, recently described by Mr. A. B. Gahan,[1] also attacks the larvæ in grass stems, kills them before maturity, and spins a gray parchment-like cocoon within the gallery, generally near its lower end. This cocoon is truncate at both ends, its disklike extremities completely filling the bore. The adult escapes by biting an opening through the stem in the vicinity of the cocoon.

ARTIFICIAL CONTROL

From the foregoing sketch of the life history of the western grass-stem sawfly it seems obvious that this pest will have to be attacked while it is in the larval state. The egg and adult stages are both brief and are clearly beyond the reach of control measures of any sort. For nearly 11 months the insect exists as a helpless larva, protected only by the grass or grain stem within which it lives. If this stem could be destroyed, the larva within would perish.

The first remedy that occurs to the farmer or the student of field conditions is the burning of the stubble in the autumn or spring. It would seem a very simple matter to set fire to the stubble and destroy at least the majority of the sawfly larvæ that are hibernating in it. But when one begins to examine the infested fields it is found that the inhabited stems have been cut at the ground level or below so that it is often necessary to brush away the earth in order to find the stubs containing the larvæ. So little heat is generated when stubble is burned that these subterranean stems could not possibly be harmed by the quick passage of the flames.

In 1907 Mr. Norman Criddle, in Manitoba, wishing to make a thorough test of this particular remedy, spread a layer of straw several inches deep over an infested area in a wheat field and set the straw on fire. More heat was produced than stubble alone could possibly make, the surface of the ground being too warm for the hand after the fire had died down. Even after this severe treatment it was found that, as far as could be learned by a minute search, not a single larva had suffered. They had simply retreated to the lower end of the hibernation cell and "kept cool."

Another fact must be noted in this connection. When a field has been damaged seriously by the sawfly, the stubble remaining to feed a running fire is of necessity more scanty than in an uninjured field

[1] Gahan, A. B. Description of a new hymenopterous parasite (Braconidæ). *In* Proc. Ent. Soc. Wash., v. 20, no. 1, p. 18–19. Jan., 1918.

and consequently it would be exceedingly difficult to burn such a field even under the most favorable conditions.

In Utah the bunch grass, *Elymus condensatus*, is much infested by this same fly and frequently is burned by fires that sweep the mountain side. This Elymus forms dense sods, with stems often more than 3 feet in length, and the heat from its combustion is great. The writer has examined a large series of burned sods and has seldom discovered any injury to the larvæ from the fire.

These facts would indicate the futility of burning the stubble as a control measure.

Although it might seem possible to decrease the numbers of the fly by mowing roadside and fence-row grasses during July, thus destroying the larvæ always present in the stems of these grasses, careful study has proved that a large percentage of the larvæ in these grasses is parasitized and therefore it would seem unwise to take steps that might diminish the number of parasites. Without any doubt grain fields in North Dakota and Canada are invaded regularly by sawflies that issue from grass growing along their borders. Still, because of the multiplication of useful parasites from this same grass it is probably inadvisable to mow the grass in midsummer.

Deep plowing, 5 to 6 inches, is perhaps the best remedy for the sawfly that can be suggested at present. It is much easier to advise this than to put it in practice. In almost every plowed field in any part of the country each furrow is marked by a row of stubble projecting from the inner edge of the furrow slice. Unless the stubble is turned squarely upside down, burying it at least 5 inches, the resulting surface at the same time being compacted by harrowing or rolling, the flies will be able to escape with ease from beneath the ground.

In the fall of 1916 the writer buried four lots of infested stubble in different depths of earth sifted and compacted by jarring. These were buried, one at 3 inches, one at 4, and 2 at 6 inches, in glass jars, 10 stubs in each of the first two, 20 in the other two. August 6, 1917, these cages were examined with results as follows:

Under 3 inches of earth all adults emerged.

Under 4 inches 1 larva died, all others emerged.

Under 6 inches 1 adult died in the cell, 6 larvæ also died, 2 active living larvæ still in the cell, all other adults emerged.

Under 6 inches 7 larvæ died in the cell, all other adults emerged.

Lumpy soil in the field might make it easier or harder for adults to emerge than fine soil in a jar, and this point might be difficult to determine.

Cultural conditions in North Dakota are not favorable for burying the stubble by plowing. Spring wheat is followed in many cases by winter rye which is disked into the wheat stubble after harvest. This

procedure leaves all the infested stems of wheat on the surface, and nothing could be more favorable for the escape of the adult flies in the following spring. The wheat stubble seems to be necessary to hold the winter snow for the protection of the young rye, hence the farmers seldom or never plow the stubble under before sowing the rye.

Previous to the year 1919 it had been stated with much confidence by men who were known to be good observers that durum wheat was nearly immune from the attacks of the sawfly. On the strength of these statements county agents were inclined to recommend a modification of ordinary farm practice, at least to the extent of barring from that region Fife and Marquis and the softer-stemmed wheats in the hope that by this means the work of the sawfly might be checked and a more certain harvest assured. It was readily seen that an immune wheat would solve the problem of the sawfly.

Observations made by the writer during the month of August, 1919, and recorded on an earlier page of this paper, included in their scope an inquiry into this question concerning the immunity of durum wheat. Farm work was too far along at the date of this visit to permit of effective field work to settle the matter definitely, but several farmers informed the writer that durum had suffered severely that year, although not as much as either Fife or Marquis. These reports must be accepted at their face value since the agreement on this point was general.

The immunity of durum may vary from year to year and is possibly based on the relative dates of the appearance of the adult Cephus and the rapidity of growth of the young grain. The stem of the durum wheat is more dense and unyielding than that of other wheats, and if a warm rainy spring should hasten its growth it might prevent the sawfly from placing many eggs. A number of unknown factors enter into this problem that hinder its complete solution at the present time.

CEPHUS PYGMAEUS L.

In certain parts of the country the occurrence of *Cephus cinctus* appears to have been confused with that of its congener *Cephus pygmaeus*, a sawfly stem-borer that was probably imported from Europe only a few years previous to the first mention of *Cephus cinctus* in the United States. The habits of the two species are so similar that a brief synopsis of the life history of *Cephus pygmaeus* is given herewith together with a condensed description of the same insect.

As far as is now known the imported species does not yet occur west of the Mississippi River, while the western grass-stem sawfly has been found for the most part only west of the same river.

C. pygmaeus was first observed in 1887 in the vicinity of Ithaca, N. Y., and in 1889 Prof. J. H. Comstock published [1] an account of its

life history as worked out by himself. From this bulletin the following summary of its habits and appearance has been compiled.

The adults, in the latitude of Ithaca, appear during the month of May and at once begin oviposition in the stems of wheat, just as the grain is jointing. In the majority of instances the eggs are placed above the third joint, and the larval gallery extends from the point of oviposition, or a little above, to the extreme base of the plant. By the time the wheat is ready to cut, early in July, a large majority of the larvæ have descended to a position below the level of the reaper cut and are safe from removal with the harvested straw. A week later nearly all the larvæ have girdled the stems within and part have already spun the silken lining of the hibernation chamber.

Cephus pygmaeus is a well-known species in Europe and has been described by both English and Continental writers. In France it has been considered a very serious pest and is said to attack both wheat and rye.

DESCRIPTION

Adult shining black, banded and spotted with yellow. Length of male 8 mm., of female 10 mm. Head large with prominent eyes; three ocelli near summit. Antennæ inserted on front nearly opposite middle of compound eyes, and composed of 19 or 20 segments. Wings transparent, iridescent, somewhat smoky, with costal margin yellow toward base. Mouth-parts (except tips of mandibles), a spot on clypeus, a narrow margin between compound eyes and mouth-parts, ventral aspect of thorax, legs (except a dark band on coxæ and femora), membrane at base of abdomen, caudal margin of each abdominal segment ventrally, a more or less well-marked spot on each side of first and second abdominal segments, a broad band occupying caudal three-fourths of third and fifth segments, a narrow band on caudal margin of sixth segment often more or less interrupted forming spots on back and sides, and latero-caudal angles of seventh segment, yellow in male.

In female, spots and bands usually smaller and sometimes entirely wanting ventrally.

Both this species and *Cephus cinctus* vary greatly in their markings. Mr. S. A. Rohwer, of the Bureau of Entomology, who has given much critical study to this genus and has examined a large series of individuals, mostly reared from known host plants, states in a recent publication:[2] "The introduced, European, *Cephus pygmaeus* (Linnaeus) is very similar to the native species common throughout the west and it is difficult to find characters which distinguish the two in all their forms."

[1] Comstock, J. H. A saw-fly borer in wheat. *In* Bul. 11, Agr. Exp. Sta. Cornell Univ., Nov., 1880.
[2] Rohwer, S. A. The American species of the genus Cephus Latreille. *In* Proc. Ent. Soc. Wash., v. 19, p. 126-141. 1917.

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